

PLANTS
AND THEIR WAYS

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PLANTS AND THEIR WAYS

AN INTRODUCTION TO THE STUDY
OF BOTANY & AGRICULTURAL SCIENCE

BY

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MANY ILLUSTRATIONS

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Oh for a breath of the moorland,
A glimpse of the mountain grey,
For the thyme and the fragrant myrtle,
That scent the wanderer's way !

Oh for the grey loch sleeping,
Where the swallows skim and glide,
For the bracken softly swaying,
On the mountain's rugged side :

For the sound of the burn that wimples,
And sparkles in its fall :
For the gleam of the purple heather,
Where the lonely curlews call !

Oh for the far moor stretching
To the blue and distant hills :
For the grace of the purple twilight,
When the mist the valley fills !

W. CUTBERTSON.

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PLANTS AND THEIR WAYS

CHAPTER I

INTRODUCTION

NATURE-STUDY.—Most persons must have been struck by the great interest taken by the general public in what has been termed Nature-study or Nature-knowledge. Again and again, definitions have been given to state what is meant by Nature-study, and to point out its position among the sciences. For nature-study is not a branch of science, but it owes much to science, and uses the scientific method in investigating nature. For the object of this book it can be defined as “the power of observing correctly the structure, mode of life, and functions of plants.” It can be used as an introduction to the study of biology, and through that science to a correct knowledge of botany. Undoubtedly the best place to study nature is in the open air, and to see living beings as they exist in a wild state, but useful work can be done in the laboratory and lecture-room. Much information on nature-study can be obtained from books, but, in all cases, this should be tested by work in the laboratory and in the field. Many of the terms used in botany can be used in describing plants, and throughout the following pages they will be introduced where needed. In far too many cases, the would-be student of nature-study has tried to study it from books alone, with the well-known result, of disgust, and the

determination to leave it severely alone. The student, to be successful, must learn to draw correct deductions from the objects chosen for study, and, in all cases, any dispute must be settled by an appeal to the plant.

THE AIMS OF NATURE-STUDY.—One of the aims of nature-study is to train the eye to observe, and the mind to draw correct conclusions from the material under observation. Far too many people go through the world, and see nothing in the true sense of the word. It is one of the aims of nature-study to remedy this, and to open the eyes of those who cannot see the wonders of nature. It also seeks to produce the habit of mind which enables its possessor to cultivate a love of the beautiful, and to take interest in the field, hedgerow, stream and sea. It seeks to develop refinement, and humility. This comes from a study of living beings, for the student soon realises that only very little is known of the working of nature, and that the mind of man is still a long way from solving all the great problems which nature presents to the student. Another of its aims is to improve the physical development of the coming race, by working and walking, as far as possible, in the open air, and to show to all the benefits derived from a life spent away from stuffy rooms and with nature in the open air. It tries to develop the love of nature which is such a valuable aid to happiness.

THE VALUE OF NATURE-STUDY.—The value of nature-study does not consist in the amount of information obtained, as much as in the habit of mind which it produces, and in the cultivation of the powers of observation. These will be found useful in all walks of life, and enable their possessor to command success. In addition to the utility of such a study, there is the happiness and pleasure which can be obtained from a knowledge of nature. The country walk, the ramble along the sea-shore,

and the rocks, plants, and animals one meets with on a journey all help to make up the sum total of a happy and useful life. When the love of the country is once developed in an individual, it never dies, and it enables many happy hours to be well spent in a study of Nature and her ways.

OBJECTS USED FOR NATURE-STUDY.—Numerous objects exist which can be used for nature-study, and as a rule they cost very little. Plants can be obtained in both town and country: germinating seeds, seedlings, experiments in plant physiology, and how plants grow will supply materials for numerous lessons. The plants which grow in hedgerow, in the fields, by the sea, on the moors and mountains all help the student of nature-study to obtain a true grip of the wonders of Nature. Nothing is too simple or too complex for useful lessons to be drawn from them.

THE RESULTS OF NATURE-STUDY.—The results obtained by a course of nature-study cannot be overstated. For they set the student on the high road to investigate and discover some of the wonderful secrets which nature will give up to the sympathetic investigator. It arouses in the minds of both teachers and students a sympathetic spirit, and the desire to know more of the wonderful world in which we live. It also enables the student to see that knowledge can be obtained by all who seek her in the lanes, woods, fields, etc. There are so many cases on record of young men and women who have been set on the high road to success in life by a proper appreciation of the wonders of nature, that all should consider the desirability of obtaining the power of observing and drawing correct conclusions from the various objects observed.

METHODS.—It is proposed to restrict the objects treated

of in this book to plants, and to select only very common ones for study. Those selected will be easily obtained, and they will be treated from a practical point of view. Many persons advocate that the heuristic method should be adopted in teaching nature-study, but a combined lecture and practical course will give better results. The lecture should precede the practical work, and the latter is generally based on the former. For a number of years the above method has been used by the author in his school, and large numbers of students have been stimulated to proceed with the subject after they have passed through the course. The heuristic method may be a success in the hands of some teachers, and with students who have unlimited time at their disposal, but for the great mass of humanity, the above method will give far better results. The student should carefully work through the experiments given in the following pages, and try to cultivate the powers of observation by drawing conclusions from the experimental work performed.

CHAPTER II

THE STRUCTURE OF FLOWERS

FLOWERS.—Many a sea cliff, country lane, meadow, wood, garden, and home is made bright and beautiful by flowers. Their colour, shape, and perfume help to give a characteristic appearance and aroma to thousands of landscapes. All lovers of nature revel in flowers, and they express the poetry of plant life better than probably any of its varied aspects. They often fill the homes of rich and poor with perfume and colour, and they bring within the reach of most people one of the refining influences of nature. English literature is full of the delight which follows from a knowledge of flowers. The more one knows of their structure the more wonderful they appear, and the greater the inspiration which can be drawn from them. It is proposed to give in this chapter an outline of the structure of a few common and easily obtained flowers.

PRACTICAL WORK.—The advantages of the practical method of studying the structure of flowers cannot be overestimated, and the student should work through the following exercises with the flowers before him so as to obtain correct ideas of the structure and arrangement of the different parts. As far as possible simple language will be used in describing the flowers, but technical terms will be introduced wherever necessary.

1.—PRACTICAL WORK TO ASCERTAIN THE STRUCTURE OF THE FLOWER OF THE STOCK.—Obtain the flower of the Stock, and make out the parts

described below. If there is any difficulty in obtaining the flower of the Stock, the flowers of the Wallflower, Cabbage, Mustard or similar ones can be substituted.

Calyx.—Note on the outside, and at the base or the bottom of the flower, a light green cup, which is known as the *calyx* (Fig. 1, *Ke*). It is made up of four separate green floral leaves—the *sepals*. Two of the sepals are

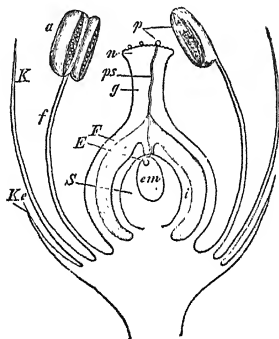


FIG. 1.—Diagram of complete flower. *Ke*, calyx; *K*, corolla; *f*, filament of stamen; *a*, anther, showing pollen grains in position and on stigma; the central portion is the pistil, and it consists of *n*, stigma; *g*, style; the swollen portion is the ovary; *S*, ovule; *E*, oosphere; *em*, embryo sac; *i*, nucellus; *F*, integuments.

swollen, these are the lateral *ovules* (at the sides); one is in front, and one behind. The calyx is fixed on to the flower stalk, in such a position as to be below all the other parts of the flower. Such a calyx is said to be inferior because it is fixed below the central part of the flower.

Corolla.—Inside the calyx a series of separate coloured floral leaves will be seen; these form the *corolla*. It is made up of four separate leaves—the *petals*, and each

petal alternates with a sepal. The corolla is fixed on the flower stalk at a slightly higher level than the calyx.

Stamens.—Remove the calyx and corolla, and find the six free stamens. The two outer stamens are short, and the four inner ones long. Note at the base of the short stamens, the swollen portions of the flower stalk, or *receptacle*; these form a pair of nectaries, and the nectar they form is stored up in the lateral sepals. From this it follows that the short stamens must be lateral, two of the long ones being anterior (in front), and two posterior (behind). They are fixed to the flower stalk so as to appear to spring from beneath the pistil. Each stamen consists of a stalk or filament, and this supports a head, or anther (Fig. 1, *f*, *a*). Touch an anther, a fine dust is left on the fingers; this is known as *pollen*.

Pistil.—Remove the stamens, and note in the centre of the flower an elongated body—the *pistil*. It stands in such a position at the top of the flower stalk that all the other parts of the flower are fixed below it, and for this reason it is *superior*. The whole of the pistil is built up of two leaves—the *carpels*. In the pistil there can be distinguished three parts: the bottom or swollen part—the *ovary*; a short constriction—the *style*, which is above the ovary; and a *stigma*, which is divided into two lobes. Open the ovary, a series of small bodies will be seen; these receive the name of *ovules*, and they are protected by the walls of the ovary.

2. — PRACTICAL WORK TO ASCERTAIN THE STRUCTURE OF THE FLOWER OF THE SWEET PEA.

—Obtain a few flowers of the Sweet Pea, and examine one, noting the arrangements of the parts described below.

Flower.—Remove in turn the calyx, corolla, stamens, and pistil of one flower, laying them out in order on a sheet of paper. When a flower is made up of the number

of parts enumerated above, it is said to be *complete*. If both stamens and pistil exist in a flower it is *perfect*. When any part of the flower is absent, it is said to be *incomplete*, and if either the stamens or pistil are absent, *imperfect*. Try and divide another flower into two equal halves, and note that this can only be done in one plane. Such a flower is *irregular*. If a flower can be divided in any plane into two equal divisions it is *regular*. The colour of the flowers may vary, but they are always sweet-scented.

Calyx.—Note the five sepals which are united to form a green cup, and that this is fixed on the flower stalk at a lower level than the other parts of the flower—*inferior*. It is hairy, and shows five lobes.

Corolla.—There are five coloured petals in the corolla. One of these is very large, and receives the name of the *standard*. The two at the sides are known as *wings*, and the two which cling together form the *keel*. The petals are fixed on the calyx.

Stamens.—Find the ten stamens; note that nine are joined by their filaments to form a tube, and that one is free. Pass a pin into the slit on the side of the free stamen. This slit is to allow of the tongue of a bee to enter the tube in search of nectar. The stamens, like the petals, are fixed on the calyx. Examine the anthers, and note how they are fixed to the filaments.

Pistil.—Remove the united stamens, and the pistil will be exposed to view. This is formed of a single carpel, and the long green portion at the base is the ovary; the bent portion, the style—which bears at its apex the stigma. The pistil is superior. Hold the ovary up to the light, a row of ovules will be seen through the walls. Note the ring of swollen material at the base of the pistil; this forms a nectary.

3. — PRACTICAL WORK TO ASCERTAIN THE STRUCTURE OF THE FLOWER OF THE WHITE DEADNETTLE.—Obtain a White Deadnettle, and examine its flowers. This plant can be obtained in flower nearly all the year, but other kinds of deadnettles can be used in place of it.

Flower.—Remove one flower, and note that it is complete and perfect. It is irregular, white, and does not possess any sweet scent.

Calyx.—The calyx is made up of four united sepals; it is inferior, green, and hairy.

Corolla.—The corolla is made up of five united petals, and it will slip off all in a piece. The corolla is fixed below the pistil. It is white and hairy.

Stamens.—Open the corolla lengthwise, and find the four stamens. The stamens are in two pairs, which are of different lengths. Note how the stamens are fixed to the corolla, and the anthers to the filaments. The filaments are white and hairy.

Pistil.—Examine the interior of the calyx, the pistil will be seen inside. Note it is made up of two carpels, each of which consists of two lobes, so that a four-lobed ovary is produced. The pistil is superior, the style is long, and springs from the base of the ovary, and the stigma is divided into two lobes. Ovules will be found inside the ovary.

4.—PRACTICAL WORK TO ASCERTAIN THE STRUCTURE OF THE FLOWER OF THE WHITE LILY.—Obtain the flower of the White Lily, Tulip, or similar flower, and find the following parts.

Flower.—The flower is complete, perfect, regular, white, very large and showy.

Perianth.—If the calyx and corolla are identical in colour, and the leaves of similar size and shape, they receive the

name of perianth. The perianth is made up of six united leaves, and it is inferior.

Stamens.—Slit open the perianth, and find the six stamens which are united to the leaves of the perianth. Note how the anthers are fixed to the filaments, their shape and contents.

Pistil.—The pistil is superior, and consists of three united carpels. The style is long, and the stigma consists of three divisions. Cut across the ovary, and note that the ovules are numerous and fixed to the axis or centre of the ovary.

5.—PRACTICAL WORK TO ASCERTAIN THE STRUCTURE OF THE FLOWER OF THE PRIMROSE.—Obtain a

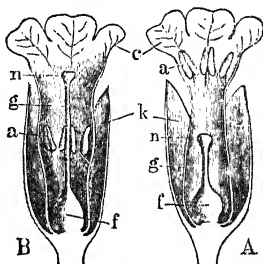


FIG. 2.—Diagram of flowers of Primrose. *A*, short-styled form; *B*, long-styled form; *k*, calyx; *c*, corolla; *a*, anther; *f*, ovary; *g*, style; *n*, stigma.

few Primroses, and make out on them the parts described below.

Flower.—The flower is complete and perfect. It can be divided into two equal halves in any direction—regular. The diameter is about one inch. It is sweet-scented, yellow, and very showy.

Calyx.—The calyx consists of five united sepals ; these are green and hairy. It is inferior.

Corolla.—The corolla consists of five united petals, and it can be removed in one piece.

Stamens.—Slit open the corolla, and find the position of the stamens. They may be fixed (1) at the top of the corolla tube, or (2) halfway down the tube. Note the number of stamens, and how the anthers are fixed to the short filaments. Each stamen faces a lobe of the corolla.

Pistil.—Remove the corolla, and note the position of the pistil. Recognise the ovary, style, and capitate, or knob-shaped, stigma. It is superior, and the ovary contains ovules. If the stigma reaches the top of the corolla tube it is a long-styled flower, and if found halfway up the tube a short-styled flower. In the long-styled form the stamens will be found at the same level in the tube as the short-styled stigma, and in the short-styled one at the same level as the stigma of the long-styled flower.

6.—PRACTICAL WORK TO ASCERTAIN THE STRUCTURE OF THE FLOWER OF THE BUTTERCUP.—Obtain a few flowers of the Buttercup, and carefully work through them to discover the structure of such a flower.

Flower.—The flower is complete and perfect, regular, about one inch in diameter, and yellow.

Calyx.—The calyx consists of five free sepals, and they are inferior, and green.

Corolla.—The corolla consists of five free petals, which are fixed below the pistil. When any portion of the flower is fixed on the flower stalk (other than the calyx) and below the pistil, it is said to be hypogynous, or beneath the female. Examine the petals, and note at the base of each petal and on the side facing the stamens a little swelling—a nectary. The flower of the Buttercup possesses five

nectaries for the production of nectar ; these are on the petals.

Stamens.—Remove the petals, and note the numerous free stamens which are fixed, like the petals, beneath the pistil ; they are hypogynous. Examine the anthers and filaments.

Pistil.—Pull off the stamens, and find the numerous carpels in the centre. These can be easily separated. The pistil is superior. If the carpels in a flower are not united, the pistil is said to be apocarpous, but if they are joined syncarpous. The flower of the Stock is syncarpous, but that of the Buttercup apocarpous. Open a few carpels, and find the ovules.

THE STRUCTURE OF FLOWERS.—We are now in a position to understand the structure and arrangements of the parts present in a flower. Each portion of the flower is said to be a modified leaf, and it can perform certain special work which makes it very useful to the plant as a whole. The sepals are floral leaves, and they help to protect the other parts of the flower when in the bud. In a few cases, their colour and shape may attract insect visitors to the flower. If the calyx is fixed above the pistil it is superior, and when below, inferior. The sepals may be united or they may be free.



FIG. 3.—Closed head of flowers of Dandelion, showing involucre of bracts.

The petals are floral leaves, and as a rule they are brightly coloured and sweet-scented. They serve to attract insect visitors, by their colour, shape and perfume. In some cases they may help to protect the stamens and pistil from the action of dew and rain, and to do this the corolla closes up during rain and at sunset.

The student should note in the field the closing of flowers at the approach of night, and how they open soon after the sun rises in the morning.

The stamens also are floral leaves, and the arrangement of the filaments and anthers varies in different flowers. This is well illustrated by the Buttercup and the Sweet Pea. If the student will compare the structure of these flowers the difference will be made clear. Anthers perform the very important work of producing pollen, for without it seeds cannot be produced. The shape, length and arrangement of the filaments and anthers have to do with the distribution of pollen.

The pistil, like the other parts of the flower, consists of floral leaves which receive the special name of carpels. In the Pea, the pistil is composed of one carpel, but in the Wallflower of two carpels. Carpels form the whole of the pistil, and they run from the base of the ovary to the top of the stigma. Thus the three lobes of the stigma of the White Lily lead us to believe that the pistil is composed of three carpels. There are cases where this rule will not hold good, for the capitate stigma of the Primrose gives the idea that only one carpel is present, but five carpels enter into its composition. From the ovary, ovules are produced, and it protects and nourishes them. The pistil forms the fruit, and the ovules become the seeds.

Bracts.—In many plants there will be found, at the base of the flowers, a number of small leaves which are known as *bracts*. They are generally green, but may be coloured or membranous as in the Daffodil. The flower head of the Dandelion is surrounded with numerous bracts, and these form an *involucre*; such a structure protects both the young and mature flowers from being injured by dew and rain.

CHAPTER III

THE FUNCTIONS OF FLOWERS

FUNCTIONS.—In the last chapter we considered the structure of some common flowers, and noticed that the examples examined were built up of different whorls which are known as calyx, corolla, stamens, and pistil. We have now to consider the functions of the flower, or what the flower can do which renders it useful to the plant. The best way to discover what the flower can do, will be to proceed by the experimental method to investigate the functions of some common flowers.

7.—PRACTICAL WORK TO ASCERTAIN THE FUNCTIONS OF STAMENS.—(1) Open carefully four young flower buds on a Fuchsia plant, and with a pair of sharp scissors remove the stamens. Now close the buds, and tie over each a piece of fine muslin to form a loose bag. (2) Select four more flower buds, and tie over each a piece of muslin to form a loose covering. (3) Mark four flower buds with Indian ink, and allow them to open in the usual manner. Similar experiments can be performed according to the season on flowers such as the Tulip, Lily, etc. Examine from day to day the ovaries of the flowers from which the stamens have been removed, and compare them with those protected by the muslin bags, and with the unprotected flowers. The ovaries of the unprotected flowers will be found to have swollen, but on those from which the stamens have been removed or have been covered over from the first with muslin there is no sign of change. Why should the ovaries of the unprotected flowers swell,

while those which have had the stamens removed or have been covered up undergo no change? We will now proceed to discover why.

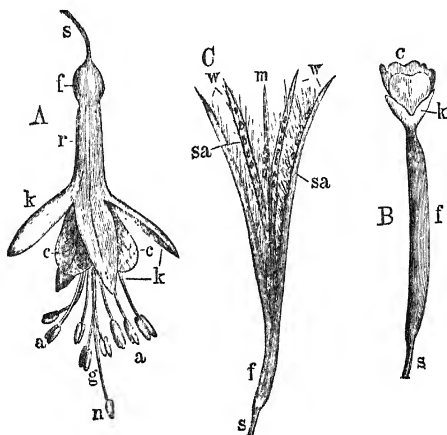


FIG. 4.—*A*, flower of Fuchsia. *B*, flower of Epilobium (Willow-herb); *s*, pedicel; *f*, inferior ovary; *k*, sepals; *c*, corolla; *a*, stamens; *g*, style; *n*, stigma. *C*, Fruit of Epilobium when liberating seeds; *w*, outer wall; *sa*, seeds with tufts of hairs.

8.—PRACTICAL WORK TO ASCERTAIN WHAT THE STAMENS CONTAIN.—Remove the pistil of one flower of the Fuchsia, and examine the stigma, which is divided into four lobes. Place a hand lens near the eye, and move the pistil so that the stigma can be clearly seen. There will be seen adhering to it numerous small bodies—the *pollen grains*. How did the pollen grains find their way to the stigma? What is pollen?

9.—PRACTICAL WORK TO ASCERTAIN WHAT IS

POLLEN.—Clear a glass slip, and place near the centre a very small drop of water. This can be done with a glass

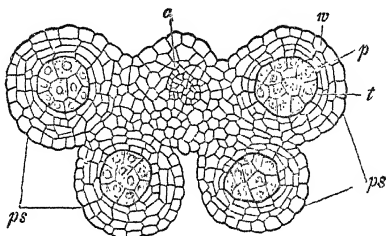


FIG. 5.—Transverse section of young anther of the Elder. *c*, connective which fastens the anther to the filament; *ps*, the four pollen sacs; *p*, the cells from which the pollen grains are developed; *t*, the cells which help to nourish the growing pollen grains; *w*, walls of anther.

rod or a pencil. Take a ripe anther from a Fuchsia, Lily, or Tulip, and brush the fine powder it contains into the

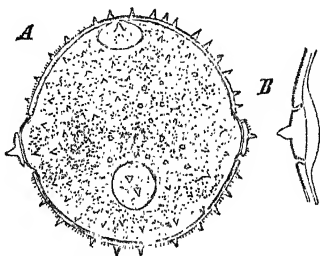


FIG. 6.—*A*, a pollen grain of Pumpkin showing the places which the pollen tubes will pierce; *B*, a section of one of the elevations. In *A* the free nuclei can be seen. (Very highly magnified.)

water. Spread it out, and examine it with a hand lens, or, better still, with a microscope. A series of numerous pollen grains will be seen. Each pollen grain is surrounded

by a wall, and its irregularities give the peculiar appearance to the grain. With the microscope, not only will the markings on the surface of the pollen grains be visible, but the contents can be distinguished. The pollen grains are cells to the botanist, and each one is a reproductive body. It seems evident that the pollen must have to do with the changes which go on in the swollen ovaries. The following experiment may help us to decide.

10.—PRACTICAL WORK TO ASCERTAIN THE STRUCTURE OF THE STIGMA.—(1) Remove one of the pistils from the flowers of the Fuchsia which was protected by the muslin. Examine the stigma with the hand lens. No pollen grains will be seen. (2) Examine the stigma. It is sticky, and the surface is somewhat irregular. The sticky nature and the irregular surface of the lobes of the stigma enable the pollen to adhere to it, so as to prevent it from being blown away. From the appearance of the stigma, it seems evident that it is adapted to receive pollen and is able to keep it moist so that germination can take place.

11.—PRACTICAL WORK TO ASCERTAIN HOW POLLEN GRAINS PRODUCE POLLEN TUBES.—(1) Melt a little gelatine in hot water, and add to it a very small piece of lump sugar. Now pour some of the fluid into a perfectly clean watch-glass, and brush into it the pollen from one or two ripe anthers. Cover with another clean watch-glass, and keep in a warm place for a few days. Examine with a hand lens; this can be done easily, for the gelatine has set fairly hard, and it can be moved towards the lens, or better still placed on the stage of a microscope and examined with the low power. Neglecting all foreign bodies, look for the pollen grains. There will be seen growing from them a number of long tubes—the pollen tubes. From this experiment it seems certain, if pollen

is kept warm, and in a substance like gelatine, that the grains germinate or grow, producing pollen tubes. Do the pollen grains act in a similar manner when deposited on the stigma? (2) Cut down the centre of the style of the Evening Primrose or the Fuchsia, and examine it with a hand lens. Numerous long tubes will be seen coming from the pollen grains on the stigma. These are pollen tubes. This proves that the pollen grains germinate on the stigma, and form pollen tubes.

12.—PRACTICAL WORK TO ASCERTAIN HOW THE POLLEN IS CARRIED TO THE STIGMA.

In spring, summer, or autumn watch a bed of flowers, and note the movements of bees or butterflies. They pass from flower to flower, and remain on them for some time searching for nectar. Carefully capture one of the insects, and examine it with the aid of a hand lens. Numerous pollen grains will be found over the general surface of the body. From the observation made, it seems probable that bees,

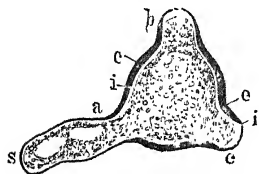


FIG. 7.—Pollen grain of *Epilobium*, or Willow-herb, showing pollen tube. *e*, extine; *i*, intine; *a*, *b*, *c*, the three thin places from which pollen tubes may protrude; *s*, apex of pollen tube. (Very highly magnified.)

butterflies, moths, etc., may carry pollen from flower to flower. It seems reasonable to suppose that the ovaries of the Fuchsia did not swell when protected by muslin bags, because they prevented insects from visiting the flowers.

The distribution of the pollen is known as *pollination*.

13.—PRACTICAL WORK TO ASCERTAIN THE CHANGES WHICH GO ON IN THE OVARY AFTER THE POLLEN IS PLACED ON THE STIGMA.

(1) Cut across the ovary of a young flower of the Fuchsia, and

remove some of the ovules; they are very small. (2) In a similar manner remove some of the ovules from a swollen ovary; they are larger than those obtained above. (3) Examine a small ovule obtained in No. 1. This can be done by fastening it to a glass slip with a little white of egg or mounting it in a drop of water. Make out with

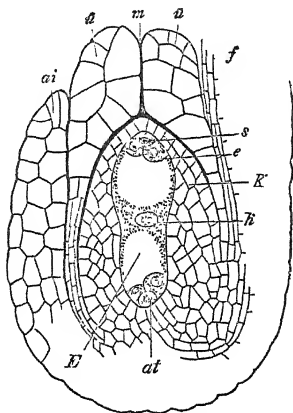


FIG. 8.—Section through an ovule, showing: *f*, stalk of ovule; *ai*, outer, and *ii*, inner integuments; *K*, nucellus; *m*, microphyle; *E*, embryo-sac; *k*, embryo-sac nucleus; *at*, antipodal cells. The egg apparatus consists of *e*, egg cell, or oösphere, and *s*, syneigidae.

the aid of a hand lens or microscope the general appearance of the ovule. (4) Examine in a similar manner one of the ovules obtained from the swollen ovary. Can you see attached to it a pollen tube? The ovule from the swollen ovary is far larger than the one examined above. The difference in the appearance of the two ovules may have

been produced by the pollen tubes. How do the pollen tubes reach the ovules, and what attracted them?

14.—PRACTICAL WORK TO ASCERTAIN WHY THE POLLEN TUBE REACHES THE OVULE.—(1) Melt some gelatine in hot water, and pour it into a watch-glass. When it has set, place in the centre an ovule, and with care deposit near the edge of the gelatine some pollen grains. Cover with another clean watch-glass, and keep warm. Examine the pollen grains each day, and note the direction in which the pollen tubes point. The majority of the pollen tubes will point towards the ovule. What is the substance in the ovule which attracts the pollen tubes? (2) Prepare a similar preparation with gelatine, but place instead of the ovule in the centre of the watch-glass a small piece of lump sugar. Place the pollen as in No. 1, and examine each day. How do the pollen tubes point? Many of them point towards the sugar.

OVULES.—It seems probable that sugar or a similar substance in the ovules attracts the pollen tubes. The pollen grains germinate on the stigma, and the tubes grow down the style into the ovary. In some cases they grow down special canals or hollows in the style, but in the majority of instances they grow between the cells of the style. The tubes then enter the ovules, and cause them to swell up.

POLLEN.—Some flowers produce pollen grains which are sticky, and they often cling together to form pollen-masses. Such pollen will easily cling to the bodies of insects, and to the stigmas on which it is placed. On the other hand, numerous flowers form pollen which is dry and dusty. This can be easily moved by the action of the wind.

POLLINATION.—From the experiments performed it is evident that the pollen must find its way from the anthers

to the stigma. The carrying of the pollen is known as *pollination*. There are several ways in which pollination can be carried out.

(1) The agents for the distribution of the pollen may be insects, such as bees, butterflies, moths, beetles, etc. ; other animals may perform similar work, as snails and humming-birds. Why do insects visit flowers? It is common knowledge that bees visit flowers to obtain nectar, and that the nectar when mixed with saliva and chewed by the bees is converted into honey. During the time that they are engaged in collecting nectar they also obtain a certain amount of pollen, and from the nectar and pollen produce the bee-bread on which they feed their larvæ. It seems a reasonable deduction that all insects visit flowers to collect nectar and pollen for food. In performing this work, they incidently distribute the pollen from flower to flower. It is evident that the sticky pollen will have the best opportunity to be transferred from flower to flower by insects.

(2) The wind may distribute the pollen, as in the cases of grasses, willows, pines, elms, and oaks. The dry, dusty pollen will be of great service in this case, for it can be moved by the action of the wind.

(3) In a very few cases water may be the medium by which pollination is brought about, *e. g.* *Vallisneria*.

FERTILISATION.—When the pollen tube enters the ovule, the tip breaks off and a portion of its contents unites with one part of the ovule ; the union of these two masses of living material is known as fertilisation. Pollination always precedes fertilisation, and all the changes which go on in ovules and ovaries are produced by the latter process.

KINDS OF POLLINATION AND FERTILISATION.—If the pollen from the stamens of a flower is placed on the

stigma of the same flower, the process receives the name of *self-pollination*. In some cases the pollen of one flower finds its way to the stigma of another flower of the same species—this is known as *cross-pollination*. The student will see from this that there are also two methods of fertilisation, viz. cross and self fertilisation. The con-

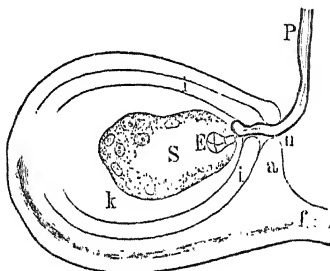


FIG. 9.—Diagram showing ovule after fertilisation. *a* and *i*, integuments; *f*, stalk of ovule; *k*, nucellus; *S*, embryo-sac; *E*, embryo; the cells in embryo-sac represent the developing endosperm; *P*, pollen tube passing through micropyle.

nection between pollination and fertilisation is shown below.

Self-pollination precedes Self-Fertilisation.

Cross-pollination „ Cross-Fertilisation.

CHANGES PRODUCED IN THE FLOWER BY FERTILISATION.—Numerous changes are brought about in the various parts of the flower by fertilisation. These changes can be discovered by observing flowers after fertilisation.

15.—PRACTICAL WORK TO ASCERTAIN THE CHANGES PRODUCED IN FLOWERS BY FERTILISATION.—(1) Observe the flowers on a window plant, and note that before

fertilisation the sepals and petals keep their shape, colour and perfume. After fertilisation notice the same flower: the petals shrivel up, lose their colour, and fall off; the ovary swells, and the ovules increase in size. (2) Select two very young flower buds, and number them with Indian ink. Protect one from insects, etc., by a muslin bag, and let the other open in the ordinary way. Observe from day to day, and note which loses its sepals and petals first. (3) In a similar manner perform experiments on plants which grow in a garden, and compare results with those obtained in No. 2. (4) Make observations on the flowers of the Willow Herb, Sweet Pea, White Deadnettle, or any other plants growing wild. Write notes of the results obtained.

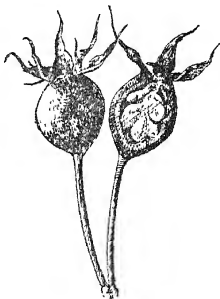


FIG. 10.—Rose Hips.

SUMMARY OF THE RESULTS OBTAINED BY FERTILISATION.—The student will have noticed that fertilisation causes the petals to fall away. They have performed their functions or have done their work of attracting insects and protecting the pollen from being moistened by dew or rain. The sepals may remain or fall away in a similar manner to the petals. After the pollen has been liberated from the anthers the stamens dry up and disappear. The most remarkable changes are produced in the ovary and ovules. These are shown below.

Fertilisation changes the ovary, and in some cases other parts of the flower, into a fruit.

Fertilisation changes the ovules into seeds.

CHAPTER IV

FRUITS AND SEEDS

FRUITS.—The changes which occur in the flower after fertilisation produces an organ which is known as a *fruit*. An *organ* is any part of the plant which performs special work. Thus the fruit is an organ because it protects the seeds, and aids in their distribution.

16.—PRACTICAL WORK TO ASCERTAIN THE STRUCTURE OF A FRUIT.—Examine a tomato, and note the stalk by which it was fixed to the plant. This was the stalk of the flower. All the parts of the flower have disappeared except the ovary, this remaining as the fruit. Cut through the tomato in a vertical direction; it is succulent or soft, and encloses a number of seeds. The whole of the fruit is known as the pericarp, and in many fruits three layers can be distinguished. These are—

The surface skin, which forms the epicarp.

The central portion, which forms the endocarp.

The portion between the above, which forms the mesocarp.

17.—PRACTICAL WORK TO ASCERTAIN THE STRUCTURE OF THE APPLE.—Select a small apple, and make sketches to illustrate its structure. This can be done by making a sketch of the whole apple. Mark on the sketch the stalk and dried-up portion at the top—the remains of the calyx. Cut through the apple, and show by a sketch the three layers and the seeds. In the apple the ovary has been enclosed by the swollen receptacle, and because this carries the calyx, the remains of this organ appears at the top of the fruit.

18.—PRACTICAL WORK TO ASCERTAIN THE STRUCTURE OF VARIOUS FRUITS.—(1) Obtain a few fruits from the Stock or Wallflower, and make a sketch of one. Now open it, and examine its contents. Down the centre

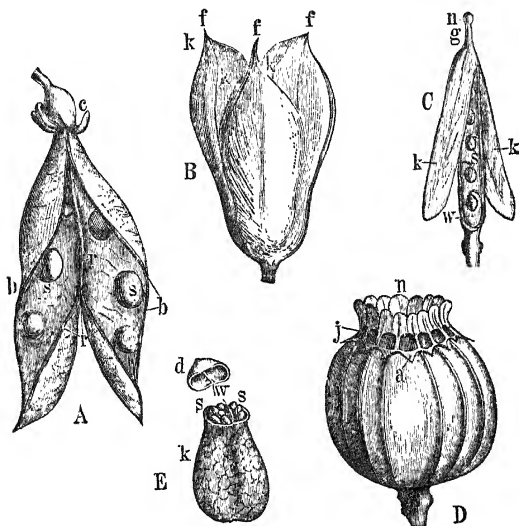


FIG. 11.—Dry fruits. *A*, pod or legume of pea; *B*, a capsule of the Autumn Crocus; *C*, silique of Braccia or Cabbage; *D*, capsule of Poppy; *E*, capsule of common Henbane.

a septum will be seen, and on this the seeds are fixed. It is a superior fruit, and, like the pistil, consists of two carpels. (2) In a similar manner examine the fruit of the Gorse. This contains a number of seeds, and these alternate on either half of the fruit. It differs from the fruit of

the Stock in consisting of only one carpel. (3) Examine the fruits of the Oak, Sycamore, Ash, Beech and Orange. Write short notes, and illustrate them by sketches.

CLASSIFICATION OF FRUITS.—The student should make a collection of fruits, and arrange them according to the following classification.

FRUITS.	EXAMPLES.
Fruits with dry pericarps.	The fruits of the Stock, Wallflower, Radish, Cabbage, Turnip, Pea, Bean, Broom, Gorse, Poppy, Sycamore, Ash, Buttercup, Monkshood, Larkspur, etc.
Fruits with some part of the pericarp soft, or succulent.	The fruits of the Gooseberry, Orange, Currant, Apple, Pear, Cherry, Plum, Grape, Rose, Strawberry, Blackberry, Mulberry, Cucumber, Tomato, etc.

19.—PRACTICAL WORK TO ASCERTAIN HOW FRUITS LIBERATE THEIR SEEDS.—(1) The student should examine the dry fruits enumerated in the above table, and determine if they split open to set the seeds free. This can be done by noticing if any pores or valves are present in the fruits, or if they split open when squeezed. The Poppy opens by pores, and the Bean, Pea, Stocks, etc., split open. (2) Succulent fruits do not split open, but decay, the seeds germinating in the fruits. Thus the soft parts of the Cherry decay, and the seed, which is enclosed in a hard endocarp, germinates, splitting open the endocarp.

HOW FRUITS AND SEEDS ARE SCATTERED.—The seeds may be scattered while still in the fruits, or, as we have seen, the seeds may leave the fruits. The following illustrates how the seeds are scattered.

1. *Fruits scattered by the Wind with the Enclosed Seeds.*—The fruits of the Dandelion, Groundsel, and those of similar plants are distributed by the wind. They are inferior fruits, the calyx being converted into a pappus of hairs, this acts like a parachute on a windy day. The fruits of the Sycamore and Ash are also scattered by the wind. The seeds germinate in the spring, splitting open the fruit.

2. *Fruits scattered by Animals.*—(a) Animals are very fond of succulent fruits, and they carry them away to eat. Thus the cherry and plum are often removed by black-birds, and the seeds become widely distributed. (b) Animals also remove dry fruits, such as nuts, and in some cases the squirrels store them away. These germinate when the

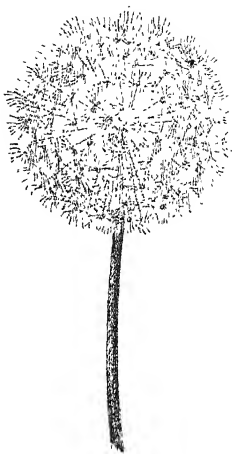


FIG. 12.—Combined fruit of Dandelion, showing the pappus of hairs by which the fruits are distributed.

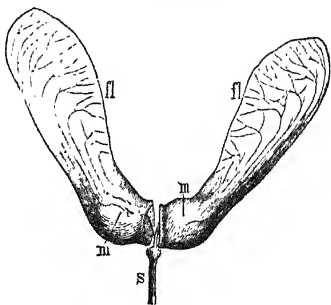


FIG. 13.—Fruit of Sycamore, showing: *s*, pedicle, or stalk; *fl*, wings; *m*, seeds.

warm weather comes. (c) Animals are often the unconscious agents for the distribution of fruits. Fruits may cling to the fur, feathers, and feet of animals. By this means they may be widely spread.

3. *Fruits which scatter their Seeds.*—Many fruits explode, shooting their seeds for a considerable distance. The Wood Sorrel and Pansy are good examples.

20.—PRACTICAL WORK TO ASCERTAIN HOW SEEDS ARE DISTRIBUTED.—

The student should, on every available occasion, examine fruits in the field, and make full notes of the methods of distribution. For instance, the range or distance to which the fruits of the Sycamore are carried by the wind might be noticed. In some cases they may be found on old walls, buildings, roofs, and on bare patches of rocks. The distribution of fruits of plants, such as the Thistles, Groundsel, and Dandelion should

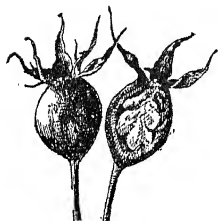


FIG. 14.—Fruits of Rose.

be noticed. A walk along a country lane in autumn or winter will generally enable one to collect plenty of examples of fruits, and make numerous observations of how seeds are scattered.

SEEDS.—By means of practical work we have already considered how seeds are produced and distributed. We will now proceed by the usual method to ascertain the structure of a few typical seeds.

21.—PRACTICAL WORK TO ASCERTAIN THE STRUCTURE OF THE SEEDS OF THE PEA.—Soak a few peas in water for 24 hours; note that they absorb a large quantity, and increase in size. Carefully examine one, and find the place where the seed was attached to the

fruit by a stalk. Gently squeeze the seed, a drop of water appears at a small opening; this opening is known as the *micropyle*, and the mark near it receives the name of *hilum*. Remove the coverings from the seed, and separate them. The outer skin is the *testa* and the inner one the *tegmen*. The two combined form the *spermoderm*. Inside the spermoderm the *embryo*, or young plant, will be found. It consists of a root or *radicle*, a pair of thick fleshy leaves, the *cotyledons* or seed-leaves, and between these a young stem, or *plumule*, will be found. When the whole of the seed is occupied by the embryo, so that there is no room for anything else, the seed is said to be *exalbuminous*. This is in contradiction to those which contain material stored up in the seed for the use of the embryo when it begins to grow—the *albuminous* seed. Make a sketch of the parts present in the seed, and see if the parts conform to those given below.

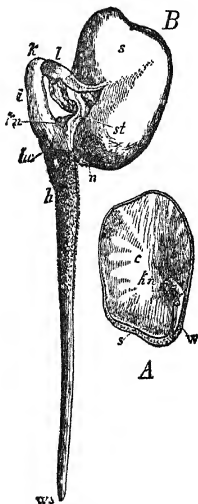


FIG. 15.—A, seed of Bean with cotyledon or seed-leaf removed; *c*, the remaining cotyledon; *w*, radicle or young root; *kn*, plumule or young stem; *s*, testa.

B, germinating seed of Bean, showing: *h*, the primary root; *ws*, apex of root; *hc*, portion of stem below first foliage leaves; *kn*, young bud in axil of cotyledon; *n*, hilum; *st*, testa; *l*, portion of testa torn away.

Pea Seed	{ Spermoderm Embryo, or young plant	{ Leaves, or cotyledons. Stem, or plumule. Root, or radicle.

22.—PRACTICAL WORK TO ASCERTAIN THE STRUCTURE OF ALBUMINOUS SEEDS.—(1) Obtain a few Castor Oil Seeds, and examine one. Find on the outside the spermoderm and micropyle. Try and strip the spermoderm from the *kernel*, as the central mass of the seed is called. Cut through a seed in a vertical direction, and examine the exposed surface. Find the embryo and endosperm. The endosperm consists of a collection of cells which contains reserve material for the early development of the embryo. (2) Make a section through the seed of the Wood Sorrel, and find the spermoderm, embryo and endosperm. (3) In a similar manner examine the seed of the Coffee Plant. (4) The Indian corn, wheat, barley, and oats can be used for comparison, but the student must remember that they are fruits, not seeds. In an albuminous seed the parts shown below can be found.

Castor-oil Seed	{	Spermoderm.	{	Kernel	{	Endosperm.	{	Seed leaves, or cotyledon.
						Embryo, or		Stem, or plumule.
						young plant		Root, or radicle.

23.—PRACTICAL WORK TO ASCERTAIN HOW SEEDS FALL ON THE SOIL.—Select a number of seeds, and allow them to drop on some sand. In the case of all the seeds used in this experiment make careful observation of the side which touches the sand. In far the larger number of cases the hilum, near which the micropyle is found, will be downwards. Why? The micropyle end of the seed has generally a greater specific gravity than the rest, with the result that the centre of gravity is near the micropyle, and this is downwards when the seed comes to

rest. Of what service is this to seeds? Water can enter the seed at the micropyle, and so it aids the seed to germinate.

SEEDS AND FRUITS.—The seeds produced by the parent plant carry on the life of that particular species, and the more widely they are distributed the better the chances that some of them will fall on suitable soil for growth. The colour of fruits and seeds, along with their shape, weight, and irregularities, have to do with distribution. Young seedlings live on the materials stored up in the seeds until they can earn their own livelihood. Food materials may be stored up in seeds (1) outside the embryo, (2) in the cotyledons. In the albuminous seed the reserve food is outside the embryo, and as germination proceeds it is used up. On the other hand, in the pea and bean or exalbuminous seeds it is stored up in the cotyledons, and at the close of germination they will generally be found empty.

Fruits aid in the distribution of the seeds; their colour shape, aroma, mode of opening, etc., have to do with this important function. Winged fruits, like those of the Ash and Sycamore, render them light in proportion to size, hence their wide distribution. There is also another advantage in having the seeds widely distributed, viz. that they do not compete with the parent plant for food supply. If all the seeds produced by the Sycamore were deposited beneath the parent tree, the seedlings would have very little opportunity of surviving in the struggle for existence. From the very first they would be shaded by the adult plant, and after a more or less keen struggle they would die.

CHAPTER V

GERMINATING SEEDS AND SEEDLINGS

CONDITIONS NECESSARY FOR GERMINATING SEEDS.—From the practical work done in the last chapter, we have seen that a seed contains a young plant, and this is made up of a radicle, or root; a plumule, or stem; and cotyledons, or seed-leaves. The embryo, or young plant, is dormant, and will remain in that condition for a considerable length of time if kept dry. How long a seed will keep its vitality is a much-disputed topic among botanists. But from the observations made with the seeds of cultivated plants, it has been discovered that immature ones develop slower than those which have been kept for two years; seeds of this age germinate quicker and produce strong plants. It has also been discovered that the number of seeds which will germinate decrease after a certain length of time. If they are kept for a period of twenty years, not above one in twenty will produce seedlings, and after thirty years hardly any will germinate. Seeds will germinate or begin to grow if kept for some time in a moist condition, and at a certain temperature. There are three conditions necessary for the germination of seeds; these are—

(1) The seeds must be kept moist, so that they can absorb water.

(2) The seeds must be kept warm, so that the heat can stimulate the embryos, and enable them to grow.

(3) The seeds must be supplied with air, so that the oxygen it contains can act on the embryos, and enable them to obtain the energy necessary for growth.

24.—PRACTICAL WORK TO ASCERTAIN HOW SEEDS GERMINATE.—Place a few Bean seeds to soak in water for twelve hours. Prepare two chalk-boxes or plant-pots, and fill them with sawdust. Moisten the whole of the sawdust with water; this can be done by placing them in a dish full of water for a few minutes. Lay about twenty seeds on the surface of each plant-pot, and cover them with pieces of glass. Place one on a window sill, and the other in a dark cupboard. Examine them each day, and note which germinates the quickest. At the end of a week remove one seedling from each pot, and make sketches to show how germination takes place. The seeds swell up, and as development proceeds, the radicle pushes its way through the micropyle, and strikes downwards into the sawdust. The plumule comes from between the seed-leaves in a bent position, and slowly straightens itself. At last the whole of the material in the seed-leaves have been removed into the young seedling, and the empty leaves decay. Those plants which germinate in the dark grow the quickest, but they are pale in colour, while those which have been exposed to light are more sturdy and green. If average specimens from each pot are taken each week, and carefully measured, a curve can be constructed for each condition of growth. Show by sketches the appearance presented by Bean seedlings when one, two, three, four, and five weeks old.

25.—PRACTICAL WORK TO ASCERTAIN HOW INDIAN CORN GERMINATES.—Soak in water for twenty-four hours a number of seeds of the Maize, or Indian Corn. Divide them between two plant-pots in a similar manner to the beans; keep them warm and moist. Place one pot in the dark, the other in the light. Make sketches, so as to obtain a series of views of the growth of the plant. The young root only grows for a short length of time, then

numerous rootlets are produced from above it—these receive the name of *adventitious* roots, because they are not developed in regular order.

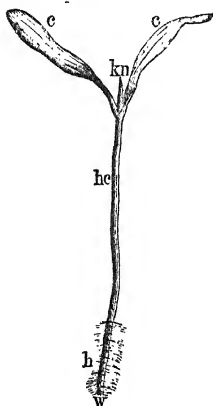


FIG. 16.—Seedling of Sycamore. *cc*, cotyledons; *kn*, the plumule; *hc*, the portion of stem below cotyledons or hypocotyl; *w*, radicle or primary root with apex cut off; *h*, root-hairs.

Contrast the methods of germination shown by the seeds of the Bean and Maize. Compare the structure of the leaves with those of the Bean, and note any peculiarities which the different seedlings show.

26.—PRACTICAL WORK TO ASCERTAIN HOW DIFFERENT SEEDS GERMINATE.—The student should perform similar experiments, using some of the following seeds:—

Peas.	Cabbage.
Vetches.	Tomato.
Almonds.	Buckwheat.
Castor-oil.	Wheat.
Sycamore.	Oats.
Mustard.	Barley.
Turnip.	

27.—PRACTICAL WORK TO SHOW DIFFERENT CONDITIONS AND THEIR ACTION ON GERMINATION.—

(1) Clean two pickle-bottles and their stoppers. Place in one some peas, and fill to the top with water, then replace the stopper. In the other bottle place some damp pieces of blotting-paper, and on these some peas. Do *not* replace the stopper. Keep both bottles under similar conditions, and at a suitable temperature. Examine each day; note how germination goes on in (i) the

bottle of water which contains very little air, (ii) the bottle which contains air. The seeds supplied with air germinate far better than those in the water. Why? Because oxygen is necessary for the healthy growth of seedlings.

(2) Fill two plant-pots with sawdust; place on each an equal number of seeds: keep one pot in a cold place, and the other near a fire. Which germinates the quickest? Why do the rates of germination vary? This experiment shows that heat is necessary for germinating seeds, and that the rate depends upon the amount.

(3) Fill four plant-pots with soil, and plant in each forty mustard seeds at the following depths: half an inch from the surface, one inch, two inches, and three inches. Keep under similar conditions, and count the number of seedlings which reach the surface in each pot at the end of one week, two weeks, etc. What conclusions do you draw from the above experiments as to the best conditions for the germination of seeds? What bearing would the experiments performed have upon the practical work in a garden or on a farm?

28.—PRACTICAL WORK TO ASCERTAIN THE ACTION OF LIGHT ON GROWTH.—Prepare three plant-pots, and plant in each a similar number of peas. Keep one exposed to light, another in the shade, and the third in the dark. Note the rate of growth, and appearance of the seedlings for not less than six weeks. Is light favourable to healthy growth? How do the stems grow? Do they bend towards or away from the light? The leaves produced by the different plants vary in size. Which produce the largest leaves?

29.—PRACTICAL WORK TO ASCERTAIN WHERE SEEDLINGS GROW THE BEST.—Prepare three plant-pots, fill two with sawdust, and the other with good soil. Plant seeds of the Buckwheat in each pot, and moisten

one of the pots which contains sawdust with water. The other can be moistened with the solution given below, and the one which contains soil should receive only water. Keep under similar conditions of temperature and light. Observations should be made of the rate of growth, etc., for a period of not less than ten weeks. Select each week an average seedling from each pot, dry thoroughly, and weigh. This will enable correct conclusions to be deducted from the experiments performed.

Culture solution to be used in the above experiment:—

- Water about one pint, or 1 litre.
- A few crystals of potassic nitrate
(saltpetre), or 1 gramme.
- A very little common salt, or $\frac{1}{2}$ gramme.
- A similar amount of sulphate of
magnesia, or $\frac{1}{2}$ gramme.
- A similar amount of sulphate of
lime, or $\frac{1}{2}$ gramme.
- A similar amount of phosphate of
lime, or $\frac{1}{2}$ gramme.
- A little dilute solution of chloride of iron.

This solution can be diluted with water, and the sawdust can be kept moist by using the mixture.

30.—PRACTICAL WORK TO ASCERTAIN THE GERMINATING POWER OF SEEDS.—Fill two plant-pots with sand, and moisten with water. Count out twenty-five mustard seeds, spread them out on the surface of the sand in one of the plant-pots. Place the same number of seeds of the Buckwheat on the surface of the other plant-pot. Note the number of seeds which have germinated at the end of a fixed time, say a week. If twenty seeds have germinated, the germinating power will equal eighty per

cent. The student should perform similar experiments, using other kinds of seeds.

31.—PRACTICAL WORK TO ASCERTAIN WHY THE ROOT BENDS DOWNWARDS WHEN THE SEED GERMINATES.—Germinate some Bean seeds on sawdust until the roots are over one inch in length. Prepare some wide-mouthed bottles. Those which have had pickles or jam in will answer for these experiments. Obtain corks which will fit the necks of the bottles. Remove a Bean seedling and pass a pin through the seed-leaves, so as to fasten it to one of the corks. Now place in the bottom of each jar a little water to keep the seedlings moist. Allow the seedling to grow, and note the direction in which the root bends. In a similar manner fix another seedling so that the root is horizontal, and allow it to grow under the same conditions. Fix another with the root pointing upwards. Cut off the tip of the root of a fourth seedling, and fix it so that the stump is horizontal. Make observations of their method of growth, and state the conclusions you draw from the above experiments.

32.—PRACTICAL WORK WITH ROOTS TO ASCERTAIN THEIR RATE OF GROWTH.—Select a Bean seedling with a root some two inches in length. Divide the two inches into twenty equal parts, and mark their position with Indian ink. Fix the seedling in a funnel so that the root points downwards, and set it in a bottle which contains a little water. Cover the funnel with a watch-glass. Observe (1) the increase in growth between the two most distant marks, and (2) where the growth is the quickest. Make drawings to scale at intervals of several days to show rate of growth. Note where the branch roots appear, and the root hairs. Similar experiments should be carried out with other seedlings.

33.—PRACTICAL WORK TO SHOW THAT ROOTS

ABSORB SUBSTANCES.—Fix two Bean seedlings in funnels, and allow one root to dip into a glass of water which contains eosin or red ink. Let the other root dip into clean water in a test-tube or vessel, and mark the water-level with a litmus pencil. Cover each funnel with a watch-glass. The root which dips into the coloured water absorbs some of the solution, and is stained a deep red far above the level of the water. The decrease in the level of the pure water in the other vessel shows the amount absorbed. This experiment shows that roots can absorb or take in substances which are soluble in water. Nearly all the food which a plant requires is absorbed by the roots, and from the soil in which it grows.

34.—PRACTICAL WORK TO ASCERTAIN WHAT SOIL IS COMPOSED OF.—Carefully examine some good garden soil, note the dark colour, and that it is composed of particles of rock. If possible, pass the soil through a coarse sieve, so as to remove the largest fragments. Thoroughly dry some of the soil in an oven. Weigh out one ounce or fifty grammes of the dry soil, and place in a tumbler. Now allow a steady stream of water to fall on it for about an hour, stirring with a glass rod from time to time. Now drain through a sieve, and dry again. Weigh. The loss in weight roughly equals the amount of soluble material it contained. It is this soluble material which the roots of plants can absorb from the soil.

GERMINATION.—When a seed germinates, as the above experiments have shown, the radicle, or young root, bends downwards, and grips the soil before the plumule, or young stem, appears. The student will see the advantages to the seedling of the root penetrating the soil. In the first place, the seedling is firmly fixed to the soil, and it absorbs water which contains food materials. That this

is of advantage to the seedling can be shown by cutting off the root, when the growth made is very slow. The plumule is supported by the root, and the reason for its later development is at once apparent. It would be a positive disadvantage to the plant for the stem which is clothed with leaves to be elevated into the air, until a well-formed root-system had been developed to supply it with water. It is also an advantage to the plant, as well as to the gardener or farmer, for the root to turn downwards when it leaves the seed. Just suppose roots did not possess this important property; it would be necessary for the farmer or gardener to place all the numerous seeds—say a pound of turnip seeds—with the micropyle downwards in the soil. What work it would produce! There is no doubt that the bending of the root downwards and the stem upwards must be of advantage to the young plant. The seedling also lives on the reserve material in the seed, or on the substances already in the seed-leaves. After germination only the empty husks of the seeds are left behind, the whole of the nutritive material being used up by the developing plant.

LIGHT AND GROWTH.—The stem grows quicker in the dark than in the light, but the leaves generally remain small. On the other hand, the leaves become fully formed in the light, and the stem is short and sturdy. Roots turn away from the light, but leaves towards the source of light. This is well shown by window plants, for the stem, if examined, will be seen to be parallel to the rays of light, and the leaves place themselves at right angles to it.

THE SOIL AND THE PLANT.—From the practical work done the conclusion can be deducted that plants grow far better in good garden soil than in sawdust, and better if fed with the culture solution than with pure water. The

soil is composed of particles of broken-down rocks, along with vegetable matter which gives to it the dark colour already noticed. Most soils are composed of sand, clay, lime, small stones, with the remains of roots, stems, and leaves, which receive the name of humus. Good soils will hold a fair amount of water, and they contain soluble materials. It is only in such soils that seedlings reach their fullest development and become full-grown plants. We shall consider in a later portion of the work the wonderful faculty by which plants obtain the food they require.

STRUCTURE OF SEEDLINGS.—The young plants when they appear from the seeds and grow in the soil and external air are objects of interest to students of nature-study. The radicle of the Pea becomes the main, or primary, root of the seedling, and it produces a series of branches which receive the name of secondary roots. From these other roots arise, and on all the newer portions of the roots small hair-like bodies grow; these are the root hairs. They are well shown on the root of a germinating mustard seed. The root hairs absorb water from the soil, and as the roots increase in length they die off on the older portions, new ones being produced near the tips of the roots.

The plumule in a similar manner becomes the main stem of the plant, and from it branches and leaves are produced. Even the thick stem of the oak has been formed from the thin plumule of the seedling. The first-formed green leaves of the seedling may vary very much from those of the adult plant. This is well illustrated by the seedlings of the Sycamore, where the first leaves are narrow, long, and thick, but those of the adult plant are divided into lobes.

CHAPTER VI

GROWING-POINTS

GROWING-POINTS.—The student will have noticed from the practical work that the seedling possesses two points at which growth takes place. One of these comes near the apex of the plumule, and the other close to the tip of the radicle. We will now consider the structure of the growing-points, and how they are protected from injury.

35.—PRACTICAL WORK TO ASCERTAIN THE POSITION AND STRUCTURE OF THE BUDS ON THE HORSE CHESTNUT.—From a Horse Chestnut during autumn select a twig or branch which bears buds, and note where they grow. At the apex of the twig or branch a very large bud will be found—the *terminal* or *apical* bud. Smaller buds will be found along the sides of the branch—the *lateral* or *axillary* buds. Most buds are produced in the axils of leaves, and even if the twig bears no leaves, the scars left by them mark the positions which they once occupied. Axillary buds grow in the axils of leaves, or in the space enclosed by the stem and leaf, and the base of



FIG. 17.—A twig of the Horse Chestnut, showing leaf scar.

the leaves protects them from injury. Each leaf scar shows a series of marks which looks like a horseshoe (Fig. 17). The position of the buds and leaves or scars should be shown in a sketch. (2) Examine the outside of the terminal bud. It shows a series of overlapping scale-leaves, the outside of which secrete or form resin. The sticky nature of the buds on the Horse Chestnut protect them from being eaten by animals, and the resin acts like a waterproof coat on a man. Remove a scale-leaf. The interior is lined with numerous hairs, and these help to keep in the heat. Thus the resin on the outside prevents the entrance of water and animals, while the hairs on the inside keep the enclosed parts warm, just as the nap of a blanket prevents the loss of heat from the body it encloses. (3) Carefully remove the scale-leaves so as to expose the young foliage leaves within. Count the number of leaves in the bud. In all the buds examined by the author the number present have been six. Remove the leaves and lay them on a sheet of paper. Now make sketches to illustrate their appearance. Such buds are known as winter buds, so as to distinguish them from the swollen or spring buds. Both kinds of buds are identical in structure, only the spring ones are the largest. (4) Examine the apex of the stem which was enclosed in the bud--this is the growing-point. (5) Cut a section through a well-developed bud, so as to pass downwards from the apex. The growing-point will be seen to be protected by the overlapping leaves. (6) Compare the structure and appearance of (1) the terminal bud with that of the lateral one; (2) a bud in autumn with one in spring.

36.—PRACTICAL WORK TO ASCERTAIN THE STRUCTURE OF THE BUDS ON THE SYCAMORE.—

(1) Obtain a good-sized branch from the Sycamore in autumn, and examine the position of the buds. In this

case, as in that of the Horse Chestnut, the one at the apex of the branch is the largest. Just behind the terminal bud a pair of very small lateral ones will be seen. They face each other or are opposite. This is true of all the lateral buds. (2) The interior of the bud is protected by scale-leaves. They differ from the scale-leaves of the Horse Chestnut. How do they differ? Remove a scale-leaf and compare with that of the Horse Chestnut. (3) Carefully remove all the scale-leaves, and count the number of the young leaves inside the bud. Four is the usual number. Make sketches to illustrate their appearance. (4) Cut lengthwise through another bud so as to pass through the apex. The growing-point will be seen to be protected by the leaves.

37.—PRACTICAL WORK TO ASCERTAIN THE POSITION OF THE BUDS ON THE LILAC.—Examine a branch from the Lilac tree, and note the position of the buds. At the apex of the stem a pair of buds will be seen, and lower down another pair will be found. All the buds of the Lilac are opposite and axillary. The apex of the branch will not go on growing, but in place of a continuation of this a pair of lateral branches are produced.

38.—PRACTICAL WORK TO ASCERTAIN THE STRUCTURE OF A BUD ON A CABBAGE.—(1) Obtain from a gardener an old cabbage stalk which carries buds. Remove a single bud, and cut through it lengthwise. The growing-point will be in the centre. Around this a series of overlapping green leaves will be seen. The only difference between the bud of a Cabbage and those already examined consists in it being larger. (2) Try and work out the arrangement of the buds on the cabbage stalk. They will be found to occupy different levels on the stalk, and each one has at its base a leaf scar. (3) Compare the structure of the young bud with a fully developed

Cabbage. The Cabbage is a bud, and the leaves are foliage leaves.

39.—PRACTICAL WORK TO ASCERTAIN WHERE BUDS ARE DEVELOPED.—The student should on every opportunity examine plants in the field to ascertain the position of the buds. The following woody plants will offer a fair selection :—

Oak.	Ash.	Gorse.
Beech.	Hornbeam.	Willow.
Spindle tree.	Laburnum.	Ivy.
Hazel.	Birch.	Alder.
Rose.	Guelder Rose.	Wayfaring tree.
Elm.	Elder.	Hawthorn.
Honeysuckle.	Poplar.	

40.—PRACTICAL WORK TO ASCERTAIN THE USES OF BUDS.—If a young Sycamore tree can be obtained for experimental purposes, the following series of experiments can be performed. (1) From the apex of one branch rub the terminal bud, and during spring notice how the other buds on this branch act during development. (2) Rub from another branch all the lateral buds. Compare the results with those obtained in Number 1. (3) From another branch remove the whole of the buds and examine from time to time. This series of experiments, if successful, will show the use of buds, and the changes which may be produced in a tree by the destruction of the buds by frost or by animals.

41.—PRACTICAL WORK TO ASCERTAIN HOW STEMS GROW.—Obtain branches from the Horse Chestnut, Sycamore, Beech, Lilac and Oak. Now find the amount of growth in length of the different stems during the last two years. The colour of the bark and the differences in thickness of different parts of the stem will

generally be sufficient to enable one to decide on the amount of growth for any given year.

42.—PRACTICAL WORK TO ASCERTAIN THE STRUCTURE OF THE TIP OF A ROOT.—(1) Remove the coverings from a bean which has been soaked in water for twelve hours and find the radicle. Now with a sharp knife or razor shave off a small fragment lengthwise through the apex of the radicle. Place on a glass slip in a drop of water. Cut a deeper layer from the radicle and place by the side of the other section, as such a small piece is called. Examine with either a hand lens or microscope. A dark inner zone will be seen, and this encloses a lighter-coloured portion—the centre of the root. On the outside of the dark zone there will be seen a layer which differs in appearance. The outer layer which surrounds the whole of the tip of the root is the *root-cap*, and this protects the growing-point from being injured by the soil. Between the root-cap and the central portion of the root comes the *growing-point*. The whole of the growth in length of the root depends upon this layer. If this should be destroyed, the growth of the root in length will be arrested. (2) Compare the structure of the tip of the radicle of the bean with that of a well-developed root of the bean. (3) The student should examine the roots of other plants, and compare results.

BUDS WHICH GROW ON STEMS.—Most buds grow in the space formed between the stem and leaf. This is known as the axil of the leaf. All the buds which grow in the axils of leaves are known as axillary buds. Several buds may be found in the axil of a leaf, one being far larger than the others. The well-developed one forms a branch, the others are reserve buds. If the branch should be injured or die away, one of the reserve buds may then become active. Many plants produce buds which are

deeply buried in the outer portion of the stem ; these receive the name of *dormant* buds. Such buds become active if the plant loses the ordinary leaves by frost, or if the leaves are eaten by animals, and when the upper portion of the stem is broken off. If the top of a willow tree is cut off, the dormant buds become active, and a large crop of willow shoots are obtained. Why? Because the upward growth is arrested, and the loss can be made good by the development of the dormant buds. It seems very probable that the production of reserve and dormant buds may be a wise provision of nature to guard the tree against injury through the loss of its branches by the wind or storm.

BUDS WHICH GROW ON ROOTS.—If the old stem of the Aspen, Lilac, or Rose is cut down near the ground, there will spring up around the stump a series of small saplings, or young trees. These are produced from the roots by the development of dormant buds. In some cases new buds may be formed on the roots if the part above ground has been injured, as in the Hawthorn. Gardeners make use of this property in the propagation of plants. They split, for instance, the root of the Rhubarb plant, and each piece when planted produces a new plant.

STRUCTURE OF BUDS.— Each bud, as we have seen, is protected by scale-leaves. These are leaves which have been modified for the special work of protecting the young leaves and growing-point which they enclose. The characters of the scale-leaves vary in different plants, as in the Horse Chestnut and Sycamore. Some of the buds may enclose flowers. This is well shown in many buds of the Sycamore, Horse Chestnut, and Lilac. Each bud when it develops forms a branch, and the growth of the axis or stem of the branch separates the leaves which were crowded when in the bud.

STRUCTURE OF THE GROWING-POINT OF STEM.

—The growing-point of the stem of a woody plant, such as the Sycamore, consists of three different layers, and from these the whole of the trunk with its leaves are developed. The external layer forms the covering of the young seedling, but this is generally replaced by the *bark* in an older plant. Just below the external layer there is a deeper layer of the growing-point, and from this the portion between the surface skin and the central part of the stem is formed. Below the two layers enumerated above comes the deepest layer of all. This forms the whole of the central portion of the young stem. The arrangement of the layers in a growing-point cannot be made out without the use of sections and a good microscope; but the following will help to make it clear.

The external layer of the growing-point produces the covering of both stem and leaves.

The internal layer of the growing-point produces the central portion of stem.

The middle layer of the growing-point produces the portion between the above.

GROWING-POINT OF ROOT.—The growing-point of the root, like that of the stem, consists of three layers. The following shows the position and uses of these layers.

The external layer of the growing point produces the covering of the young root, root hairs, and root-cap.

The internal layer of the growing-point produces the central portion of the young root.

The middle layer of the growing-point produces the portion between the above.

THE ROOT-CAP.—The growing-point of the root differs

from that of the stem in being protected by a cap of cells. In the stem protection is given to the growing-point by the parts which surround it, viz. scale-leaves, etc. If the root lengthens, the root-cap comes in contact with the soil, and the external cells are worn away. The external cells are replaced by the growing-point, which is constantly engaged in adding to the root-cap from within. The function of the root-cap is to prevent the tender growing-point from being injured as the root forces its way through the soil.

CHAPTER VII

STEMS AND THEIR FUNCTIONS

STEMS.—The portion of a plant which supports the leaves is known as the stem. Stems vary in thickness from a fraction of an inch up to many feet, and they may creep along the surface of the soil or stand over a hundred feet high. Thus the stem of the Major Oak in Sherwood Forest is hollow, but the cavity is large enough to shelter sixteen persons. On the other hand, the slender stem of the Ivy-leaved Toad-flax does not exceed a quarter of an inch in diameter. Some stems grow erect, and they are so sturdy that they can support numerous branches and leaves. Other stems are so slender that they have to support themselves by climbing over more sturdy plants or over rocks. Numerous stems grow underground, while others creep along the surface. We will now consider the structure of stems.

43. PRACTICAL WORK TO ASCERTAIN THE KINDS OF STEMS.—(1) Obtain the stem of the White Deadnettle, and notice that it can be easily broken. It is green and four-sided. Compare the above stem with that of the Chickweed. They both have green stems, and these are said to be *herbaceous*. Such plants are often spoken of as herbs. (2) Select a branch from the Willow. Try and bend it ; this can be done easily, but because of its elasticity it rebounds as soon as the pressure is withdrawn. This well illustrates the character of a *shrubby* stem. (3) The branches used in the previous practical work on buds will illustrate what is meant by *woody* stems. The Oak,

Horse Chestnut, Sycamore, and Elm produce woody stems. All stems which grow exposed to light can be divided into three classes, viz.—

Herbaceous ;

Shrubby ;

Woody.

44.—PRACTICAL WORK TO ASCERTAIN THE SHAPE OF STEMS.—(1) Note the shape of the stem of the White Deadnettle. It is square, and four rows of leaves grow from the sides. Such stems are said to be quadrangular. (2) In a similar manner examine the stem of the Stock or Wallflower. There are five ridges on the stem, and these run from the base to the apex. From the ridges five rows of leaves grow. Stems similar to those of the Stock and Wallflower are said to be ribbed. (3) Obtain branches from the Lilac and Sycamore. Note the stems are round. The student should examine all the stems which can be met with on a journey in the country, and try to arrange the examples into classes according to shape.

45.—PRACTICAL WORK TO ASCERTAIN THE CHARACTERS OF THE SURFACE OF PLANTS.—(1) Examine the surface of each specimen of stem used in the preceding practical work. Stems may be smooth, hairy, spiny, rough, green, brown, black, etc. (2) In a similar manner proceed to examine the covering of all the stems met with on a journey in the country.

46.—PRACTICAL WORK TO ASCERTAIN HOW THE LEAVES GROW ON A STEM.—(1) Obtain a plant of the Chickweed, and examine the stem. The places from which the leaves spring receive the names of nodes. In the Chickweed, they are swollen. (2) In a similar manner examine the stems of the White Deadnettle, Stock, and Wallflower. Make sketches to show the

nodes, and the spaces between them—the internodes (Fig. 18).

47.—PRACTICAL WORK TO ASCERTAIN THE INTERNAL STRUCTURE OF HERBACEOUS STEMS.—(1)

Select a piece of the stem of the Deadnettle which contains at least four nodes and internodes. Split it open lengthwise, and clear the soft pith from the centre. A number of fibres will be seen to come into view as the pith is removed. These receive the name of *vascular bundles*. Trace one vascular bundle both up and down the stem. It will be seen to come from a leaf, it then passes through two internodes, and joins on to the vascular bundles vertically below. In most square stems, four main rows of vascular bundles will be found, or they will equal the number of rows of leaves. (2) Proceed in a similar manner with the stem of the Stock. In this case five rows of vascular bundles will be seen.

48.—PRACTICAL WORK TO DETERMINE THE WORK DONE BY VASCULAR BUNDLES IN THE STEM.—Set

a piece of the stem of the Deadnettle, from which not less than six leaves grow, in a glass of water which has been coloured red with eosin or red ink. Let it remain in the coloured solution for twenty-four hours. Now slit up the stem, and clear away the pith. The vascular bundles will be coloured a deep red. Why? Because they are the channels along which water passes up the stem to the leaves.

49.—PRACTICAL WORK TO ASCERTAIN THE STRUCTURE OF A WOODY STEM.—(1)

Obtain a woody stem; the ash or oak will do, and cut a piece from it at right angles to its length. Note that the central portion is of a different nature to the rest of the stem—the pith. On the outside of the stem comes a layer of bark, and inside this, numerous rings of wood can be seen.

The number of rings will depend upon the age of the stem. If the stem selected contains a number of rings, as in the thick stem of the Laburnum, two layers of wood can be distinguished. The external or newer portion is known as the *sapwood*, and the coloured or older portion forms the *heart-wood*. On the outside of the sapwood, and not clearly shown without a microscopic section, the growing layer will be seen. This layer by its growth produces the rings of wood. Examine the rings with care ; each one will be seen to be made up of two portions : (i) a light-coloured inner layer of some thickness, and (ii) an outer darker layer. The cause of the formation of these layers is one which has been much discussed by botanists, and even yet, no satisfactory answer can be given to the question of why they are produced. But the result can be clearly stated. There is no doubt that the light-coloured layer of wood was produced in spring, and the darker one in summer and autumn. From the examination of the different rings, the kind of spring or autumn can be inferred from the thickness of the layers in each ring. In a good spring, a thicker layer of wood would be produced, but in a wet cold one a thinner layer than the average. A good growing year will be marked by a far thicker ring than during a bad one. (2) In passing through a wood-yard or where trees have been cut down, the characters of the rings of wood should be noticed, and the position of the pith. The pith is not always in the centre, and in some cases two piths can be found in a cross section of the stem.

50.—PRACTICAL WORK TO ASCERTAIN THE STRUCTURE OF CREEPING STEMS.—(1) Collect specimens of strawberry runners, and make a sketch to show the structure of a typical one. Note how the runner creeps over the surface of the ground ; roots and leaves being

produced at the nodes. (2) Obtain specimens of the Couch Grass, and find on one a stolon. The stolon creeps along the surface for a short distance, when roots are produced, and from this point rises an upright stem. Such stems are procumbent, and die down each year. (3) If possible, obtain from a gardener a specimen of *Echeveria* which shows off-sets. Examine it, and note how the off-sets arise. Each off-set produces roots at its tips, and, the connecting portion dying off, a new plant is formed.

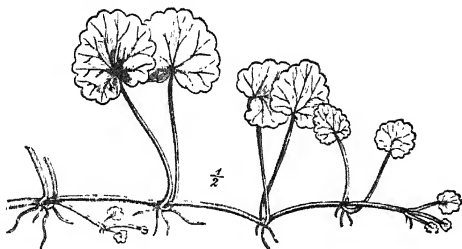


FIG. 18.—Runner of Ground-Ivy, showing roots at nodes.

(4) Many other plants produce creeping stems, and in the field these should be noted.

51.—PRACTICAL WORK TO ASCERTAIN THE STRUCTURE OF A BULB.—(1) Obtain the bulb of an Onion.

Make a sketch to show its external features. Now cut it through lengthwise, and examine the freshly cut surface. Find the very short stem, from the base of which numerous roots arise, and the overlapping leaves. Some of the leaves are very thin, others are thick and fleshy. The latter contain reserve material for next year's growth. Divide another bulb at right angles to the first division; find the flowers and axillary buds. (2) In a similar manner proceed to examine the bulbs of the Snowdrop, Tulip,

and Hyacinth. The bulb is an underground stem, and it contains reserve material for the production of flowers; etc.

52.—PRACTICAL WORK TO ASCERTAIN THE STRUCTURE OF A CORM.—Examine the corm of the Crocus, and note its structure. The corm is an underground stem, and it differs from the bulb in the stem being



FIG. 19.—Rhizome or underground stem of the Flag or Iris, showing adventitious roots, and the leaves which are produced from the growing-point.

larger and more solid. Make sections of the corm, and compare with those of the bulb already examined.

53.—PRACTICAL WORK TO ASCERTAIN HOW BULBS AND CORMS PRODUCE LEAVES AND FLOWERS.—

Obtain two glass vases and fill them with water. Place in one the bulb of the Tulip, and in the other a Crocus corm. Keep them warm and note their method of growth from week to week. What do stems produce? What do the old stems contain when growth has ceased? Why can they live on pure water?

54.—PRACTICAL WORK TO ASCERTAIN THE STRUCTURE OF A TUBER.—(1) Make a sketch of the tuber of a Potato, and mark on it the buds from which new stems will arise when growth commences. Cut through a tuber, and note the fleshy nature of its contents. (2) Place a number of Potato tubers in the dark; keep them warm and moist. The buds develop, and new stems are produced. (3) Examine a tuber of the Artichoke, and discover how it differs from that of the Potato.

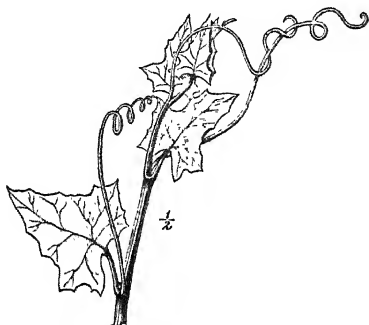


FIG. 20.—Shoot of White Bryony, showing leaves and tendrils.

55.—PRACTICAL WORK TO ASCERTAIN THE STRUCTURE OF A RHIZOME.—Select a piece of the rhizome of the Iris. This can often be found growing in damp ground, such as near streams, marshes, and even in gardens. Find on it the numerous roots, leaf scars, and growing-points. The stem is fleshy, generally light-coloured, and shows how leaves and roots are produced.

56.—PRACTICAL WORK TO ASCERTAIN BY WHAT ORGANS PLANTS CLIMB.—(1) Select from the Clematis

or Traveller's-joy a piece of the stem which shows sensitive leaf stalks. In this case the plant climbs by the leaf stalks, being sensitive, and when they touch a support they move round so as to grip it tightly. Note the twisted leaf stalks. (2) Obtain a piece of the stem of a Sweet Pea. Carefully examine a leaf, and note that the end is converted into a tendril. Tendrils are sensitive and move round in little circles. If they touch a support the movements continue until the object is tightly gripped. (3) In a similar manner examine a piece of Ivy, and note that the shady side of the stem produces numerous roots. The roots penetrate into the cracks in rocks, bark of trees, or between the bricks of a wall. They secrete a cement, and, as this dries, they become firmly united to the support. (4) Select a few stems of the Bindweed or Convolvulus. Note how they twist round each other or round a support. Such plants climb by means of twining stems.

STEMS WHICH GROW IN THE LIGHT.—The stems which grow in the light can be arranged under different heads, according to their method of growth. The following illustrates this :—

KIND OF STEMS.	EXAMPLES.
Creeping stems	Strawberry, Couch Grass, and Echeverias.
Erect Herbaceous stems . .	Deadnettle, Galium, and Wheat.
Erect Shrubby stems . . .	Gorse, Broom, Holly, and Hawthorn.
Erect Woody stems	Oak, Ash, Elm, Sycamore, and Beech.
Climbing stems	Hop, Convolvulus, Bramble, Ivy, and Honeysuckle.

STEMS WHICH GROW IN THE DARK.—Numerous stems grow below the surface of the ground, and produce shoots and leaves which break through the soil to find

light. The following gives a general classification of such stems :—

KIND OF STEMS.	EXAMPLES.
Bulbs	Tulips, Snowdrops, Hyacinth, and Lily.
Corms	Crocus and Meadow Saffron.
Tubers	Potato and Artichoke.
Rhizomes . . .	Iris, Asparagus, Solomon's Seal, and Herb Paris.

WOODY STEMS.—From the practical work done in 49 we have seen that a woody stem possesses a certain structure. A layer of bark can be seen on the outside, and this protects the deeper parts from injury. The numerous rings of wood have been produced by an active growing layer which receives the name of *cambium*, and each year it produces a ring of growth. The age of the tree can be determined by counting the number of rings present in a cross section of the stem. Trees like the Oak may live for a thousand years, and if the annual rings are examined, it is possible to make out the kind of season for any given year. Stems do not grow equally all round, but one side often shows thicker rings than the other. This unequal rate of growth in the different parts of an annual ring may be due to one side receiving less light, or containing a less number of leaves. The amount of rainfall for any given year may have a great influence on the size of the rings.

KNOTS IN TIMBER.—The knots in timber have been produced by the dormant buds enlarging each year, so that in spite of the annual rings they keep their relative position towards the outside portion of the stem. When the stem is cut through lengthwise, the position of the dormant buds can be distinguished by the knots. Loose

knots are produced in a different way. If the branch of a tree is cut off in such a way that a considerable portion of the base is left protruding, as the main stem grows new rings of wood envelop it, and, when the timber is cut through, a loose knot is seen. The same result is produced when a branch is injured.

DIRECTION OF PREVAILING WIND CAN BE OBTAINED FROM TREES.—If the direction that trees bend is noticed for any district, the direction of the prevailing winds can be determined. They always bend away from the point of the compass from which the winds usually blow. On the West Coast of Cumberland, all the trees point away from the sea, because the prevailing wind on this coast comes from the West. When the trees are without leaves, observations can be made even better than when in full leaf.

STEMS AND THEIR USES.—The following is a brief summary of the uses of stems :—

(1) Stems support the leaves, and these are so arranged that they receive the maximum amount of light.

(2) Stems connect the roots with the leaves, and through the vascular bundles which they contain the sap rises to the leaves.

(3) Stems may climb round a support so as to expose their leaves and flowers to the action of light and air.

(4) Stems may be adapted for the storing up of reserve material, for floating in water, and for obtaining food from a host plant.

CHAPTER VIII

ROOTS AND THEIR FUNCTIONS

ROOTS.—In working through Chapter V, we noticed that as the radicle forces its way through the micropyle, it responds to the pull of gravity, and turns downwards towards the centre of the earth. The radicle of the bean becomes the main root of the seedling, and it produces branches. We have now to consider the structure of roots.

57.—PRACTICAL WORK TO ASCERTAIN THE KINDS OF ROOTS PRODUCED BY A BEAN SEEDLING.—Obtain a well-grown Bean seedling, and examine the roots. Find the main- or *tap*-root, and growing from it a series of *secondary* roots will be seen. The secondary roots grow in order on the tap-root, and the youngest one will be found near its apex. Now carefully examine the secondary roots: they produce smaller ones which are known as *tertiary* roots. The Bean seedling possesses three kinds of roots; these share out the soil, and so obtain nutritive materials.

58.—PRACTICAL WORK TO ASCERTAIN THE KINDS OF ROOTS PRODUCED BY A MAIZE SEEDLING.—Select a well-grown Maize seedling. Now carefully examine the roots; noting that the tap-root is very short, and from the stem and upper portion of the root numerous other roots grow. Do these roots grow in regular order? *No*. Such roots are known as *adventitious*. The tap-roots of all grass-like plants remain short, and instead of secondary roots being produced as in the bean, only adventitious ones are formed.

59.—PRACTICAL WORK TO ASCERTAIN WHERE ROOT-HAIRS GROW.—(1) Germinate a few seeds of Buckwheat in sawdust. Now select one, and note that just behind the growing-point numerous hair-like bodies appear. Place the root in a glass of water, the root-hairs are floated out so that their arrangement can be clearly seen. (2) Compare with those on a Mustard seedling. (3) Now examine the roots of the Bean and Maize seedlings, and find the root-hairs. Compare the position in which they grow with those of the Mustard and Buckwheat seedlings. When seedlings are grown in soil, numerous particles cling to the root-hairs.

60.—PRACTICAL WORK TO ASCERTAIN THE STRUCTURE OF ROOT-HAIRS.—Mount a single seedling of the Buckwheat in water, and examine the roots with a hand lens or microscope. Each root-hair is an outgrowth of the epidermis or piliferous layer of the root, and it consists of a single cell. The root-hairs are able to pass in between the particles of the soil, and this brings the plant into intimate relation with the food materials in the soil.

61.—PRACTICAL WORK TO SHOW THAT ADVENTITIOUS ROOTS GROW ON STEMS.—(1) From an old Geranium plant remove a branch which is not less than six inches in length. Cut the end diagonally, and just below a node. Set it in garden soil. At the end of a month, carefully remove the cutting, and note that from the node adventitious roots arise. (2) In a similar manner take a cutting from a Fuchsia, and let it grow for a few weeks. Remove and examine. What results do you obtain? (3) Place a few pieces of watercress in a glass vessel containing water. Note—roots appear at the nodes. (4) Cut from a Willow a few twigs, and set them in water. Note where the roots appear. As a

general rule, they appear at the nodes, and are said to be adventitious.

62.—PRACTICAL WORK TO ASCERTAIN THE CHARACTERS OF ROOTS.—(1) Obtain and examine the roots of a Grass plant. Compare with those of the Maize or Wheat. (2) Examine the roots of the Turnip, and note that the main root is swollen. (2) It is said to be napiform, because of its shape. From the swollen root, branches grow—the secondary roots. (3) In a similar manner examine the roots of the carrot and parsnip. Swollen roots are modified to store up reserve material, and this is used for the production of flowers and seed during the second year of growth.

63.—PRACTICAL WORK TO SHOW THE CHEMICAL CHARACTERS OF ROOTS.—(1) Moisten a piece of red litmus paper and place it against the roots of a plant which has just been removed from the soil. There is no action. It is evident that the root is not alkaline, for alkaline substances turn red litmus blue. Now try a piece of blue litmus paper which has been moistened. The blue colour is changed into red. This shows that the roots are acid. (2) Try the reaction of the roots of a Mustard seedling which has been germinated on sawdust. (3) Fill a tumbler with a weak alkaline solution of litmus and set the roots of a seedling in the glass. What is the result?

64.—PRACTICAL WORK TO SHOW THAT PLANTS APPROPRIATE FOOD FROM THE SOIL.—(1) Pass some water through a quantity of garden soil, and evaporate some of it to dryness in a porcelain or glass dish. Note that a residue is left. (2) Test the water with a piece of blue litmus paper. Is the water acid? (3) Let the roots of a bean seedling dip into some of the water which has passed through the soil. (4) Set another seedling in pure water in a bottle. Allow both seedlings to grow under

similar conditions. Compare results. Which plant grows the best?

65.—PRACTICAL WORK TO SHOW THAT ROOTS CAN DISSOLVE SOME OF THE CONSTITUENTS IN THE SOIL.—

Obtain a piece of marble four inches square, and rub it on a piece of flag-stone so as to polish the surface. Place it in a box, and cover with soil. Set a bean seedling in the soil, and let it grow for six weeks. Remove the soil. A tracing of the roots can be seen on the slab of marble.

66.—PRACTICAL WORK TO ASCERTAIN WHAT SOIL CONTAINS.—

(1) Dissolve a little diphenylamine in some water, and add a few drops of sulphuric acid. Keep ready for use. (2) Now place a single crystal of saltpetre (nitrate of potash) in some water. Add to it a few drops of the diphenylamine solution, and a little strong sulphuric acid. It turns red. (3) Pass a little water through some garden soil, and to some of the water add a few drops of diphenylamine solution, and sulphuric acid. What is the result? Good soils contain in addition to ordinary minerals, substances like saltpetre.

KINDS OF ROOTS.—Plants produce roots, and these can be divided into:—

(1) *Primary roots.* The main- or tap-root is formed from the radicle of the embryo. In woody dicotyledons it is long, thick, and strong, but in the monocotyledons very short.

(2) *Secondary roots.* The secondary roots are branches of the primary roots, and they are produced in regular order.

(3) *Tertiary roots.* Branches grow in all directions from the secondary roots, and they pass in between the particles of the soil. These are the tertiary roots.

(4) *Adventitious roots.* The adventitious roots grow from stems, roots, and leaves.

(5) *Roots adapted for special work.* The swollen roots of the turnip, carrot, and parsnip act as reservoirs for the storing up of material for future use. Those of the ivy enable it to climb, and so support its leaves.

ROOT-HAIRS.—On all the newer portions of land roots fine outgrowths can be seen, these are known as *root-hairs*. Each root-hair consists of a single cell, and it can enter a very small opening in the soil. By the action of the root-hairs some of the water and the nutritive matters in the soil pass into the plant. They die off on the older portions of the roots, because the piliferous layer is replaced by a thicker covering.

WHAT ROOTS CAN DO.—Roots perform very useful work, and well-developed ones give their possessors a far better chance in the struggle which goes on in the soil for the food supply. The following gives an outline of the useful work which roots perform :—

(1) Roots penetrate the soil, and obtain such a good grip of it, that plants are firmly fixed in position. This is well shown when we consider the case of many of our forest trees. The Major Oak, for instance, with its wide-spread branches and the immense weight of leaves, is supported by its roots. This is true of all plants, both herbs, shrubs, and trees.

(2) Plants take from the soil by means of root-hairs, and newer portion of the roots, water which contains minerals in solution. The primary, secondary, and tertiary roots work all parts of the soil for food. To enable them to perform all this work to perfection, they must be supplied with plenty of air, so that the oxygen necessary for their existence can be obtained. That roots do absorb substances from the soil, is well illustrated by some of the experiments which we have performed.

(3) Roots can not only absorb material, but the acid sap

which they give out can render some of the mineral matter of the soil soluble (Experiment 65).

(4) The adventitious roots of the Ivy, and similar plants, are used for climbing. Many tropical plants which have no connection with the soil are entirely supported by adventitious roots which fix them to other plants. Such plants are known as epiphytes.

(5) Swollen roots store up reserve food for the future use of the plant. As a rule plants with such roots live two years. During the first year they store up food, and this is used up during the second year for the production of flowers and seed.

CHAPTER IX

LEAVES

LEAVES.—Most persons have examined the leaves of window plants, or those which form the head of a cabbage, and must have noticed that they are flat and green. We will now consider the way in which leaves grow on the stem, and their structure.



FIG. 21.—Cordate leaf of Ground Ivy.

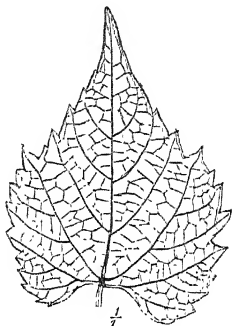


FIG. 22.—Cordate leaf of Vine.

67.—PRACTICAL WORK TO ASCERTAIN HOW LEAVES GROW ON STEMS.—Collect specimens of the Stock, Deadnettle, and Galium. Examine them with care, and in the order given above.

(1) The leaves of the Stock are arranged in five rows on the stem, and in such a manner that no two leaves are

at the same level. Such an arrangement of the leaves on a stem may be called *alternate*. (2) The leaves of the Deadnettle grow on the stem in four rows, and in such a manner that two leaves face each other. Botanists speak of such an arrangement as *opposite*. Note the position of the pairs of leaves, they are fixed to the stem at right angles to each other—*decussate*—which means “I cut across.” (3) The leaves of the Galium differ from both those of the Stock and Deadnettle, for a number grow at one level. How many leaves grow at one node depends upon the

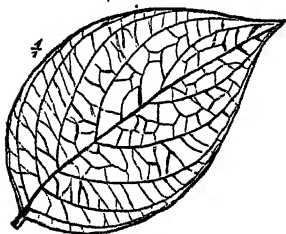


FIG. 23.—Ovate leaf of Guelder-rose.



FIG. 24.—Lanceolate leaf of Lily-of-the-Valley.

kind of Galium selected for study, for the number may vary from four to eight. Such an arrangement is known as *whorled*. More complicated arrangements can be found, but those which we have examined are the common ones.

68.—PRACTICAL WORK TO DISCOVER HOW GREEN LEAVES ARE ARRANGED WHEN EXPOSED TO LIGHT.

—(1) If a Castor-oil plant is available, set it on a window sill, and examine the position of the leaves several times a day. They will be found to occupy different positions at different periods of the day. Why? Notice the direction in which the light enters the window or falls on

the leaves. They will be seen to expose the thin green portion (blade) at right angles to the direction in which the light strikes the leaves. The leaves form a mosaic, and one leaf never shades the light from another. (2) Examine the position of the leaves of other window plants when exposed to light. They also arrange themselves in a similar manner. (3) Note the position of the leaves of the Ivy when growing on a wall. All the leaves turn towards the light; and form a mosaic. (4) The student

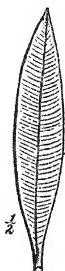


FIG. 25.—Lanceolate leaf of Nerium.

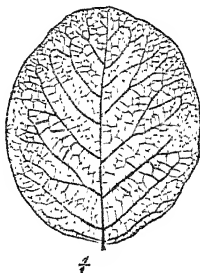


FIG. 26.—Oval leaf of Snowberry.

should on the very first opportunity make observations on the position of the leaves of various plants when growing in hedgerows, gardens, and fields. In all cases, the position of the leaves bears a certain relation to the direction of the rays of light.

69.—PRACTICAL WORK TO ASCERTAIN THE PARTS PRESENT IN A TYPICAL FOLIAGE LEAF.—(1) Obtain a Wallflower plant, and examine the leaves. Each leaf will be seen to consist of a flattened portion which is fixed by its base to the stem. The leaf is made up of only a

blade, and it does not possess a stalk. (2) In a similar manner examine the leaf of the Fuchsia. It is composed of a blade, and this is connected to the stem by a stalk—the *petiole*. (3) If the leaf of the Sycamore or some similar plant can be obtained, examine it, and note the parts present. The large lobed blade, with the stalk or petiole which is fixed to the stem by a broad portion—the *sheath*. All leaves which possess blade, petiole, and sheath, can be said to be *perfect*. If any of these parts are absent, the leaf is *imperfect*. (4) The student should examine as



FIG. 27.—Divided leaf of Cyclanthera.



FIG. 28.—Hastate leaf Orache.

many leaves as possible, to discover the parts present in each leaf.

70.—PRACTICAL WORK TO ASCERTAIN THE APPEARANCE OF THE VEINS OF FOLIAGE LEAVES.—

(1) Examine the leaf of a Fuchsia, and note the structure of the blade. There will be seen running up the centre of the blade a well-developed midrib, and from this a series of branches arise; these branch again, so that the soft parts are supported by a series of very minute *veins*. The veins of the leaf received that name because they were supposed to be hollow, and fluids circulated in them as in

the veins of an animal. This idea has been shown to be erroneous, but the sap does pass along them to the soft portions of the leaf. The leaf is generally green, and the margin may be serrated, entire, crenate, or possess spines. The lower surface of the leaf is of a pale green colour, and the upper dark green.

(2) Obtain the leaf of the Sycamore. Examine it, note that the leaf is lobed, and that a series of veins arise at the base of the blade and pass along the different lobes. From the main veins branches arise, as in the Fuchsia, so that a regular network of fine veins penetrate the whole of the blade.

(3) In a similar manner examine the leaf of the White Lily, Tulip, or Hyacinth. Note that numerous veins run parallel from the base to the apex of the leaf, and that very fine branches connect the parallel veins

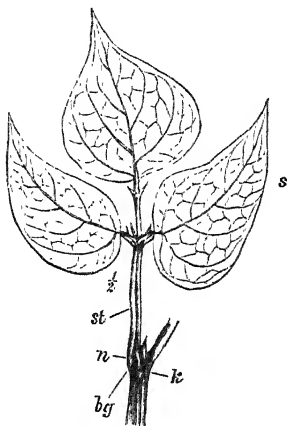


FIG. 29.—Compound leaf of Scarlet Runner. *S*, blade with three leaflets; *st*, stalk or petiole; *bfg*, leaf base; *n*, stipule; *k*, node from which the leaf grows.

together. All the leaves which grow on the higher plants can be divided into two kinds, as reticulated-veined, and parallel-veined. The former is well illustrated by the leaves of the Sycamore and Fuchsia, and the latter by those of the Lily and Hyacinth.

71.—PRACTICAL WORK TO ASCERTAIN THE DIFFERENCES BETWEEN SIMPLE AND COMPOUND LEAVES.—

(1) Obtain leaves of the Clover, Wood Sorrel, and Sweet Pea ; examine them. Both the leaves of the Clover and Wood Sorrel are made up of three leaflets, so that they differ from any we have previously examined. Each leaf is said to be compound, because the blade is divided into three divisions. This is also true of the leaf of the Sweet Pea, only the leaflets are more numerous, and the midrib is converted into a tendril. (2) Examine the leaves of the Fuchsia, Sycamore, and White Lily. Each leaf is



FIG. 30.—Compound leaf of Rose. *st*, stem ; *n*, stipules.

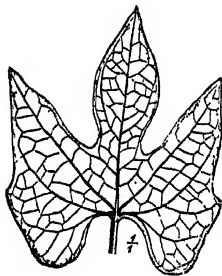


FIG. 31.—Lobed leaf of *Mimulus Lobata*.

composed of one piece, and forms a simple leaf. All leaves can be divided into two series, as *simple* and *compound*.

72.—PRACTICAL WORK TO SHOW THE USE OF THE VEINS IN A LEAF.—(1) Select pieces of the stem of the Deadnettle which carries a number of leaves. Set one piece in a glass of water, and with a pair of scissors cut through one of the midribs near the base of the blade.

Make observations of the result which arise to the leaf of the midrib being cut through, and compare with the uninjured leaves. (2) Place another piece in a glass of water which has been coloured red with eosin or red ink. Does the coloured solution stain the veins of the leaf? What conclusions do you draw from the above experiments?

73.—PRACTICAL WORK TO SHOW THE CONNECTION BETWEEN VASCULAR BUNDLES OF THE STEM AND THOSE OF THE LEAF.—(1) Obtain a well-grown plant of the White Dead-nettle, and divide it lengthwise through the stem. Clear out the pith, and trace the vascular bundles of the stem and leaf. Each one bends outwards at the node, and joins on to those of the leaf. (2) Examine in a similar

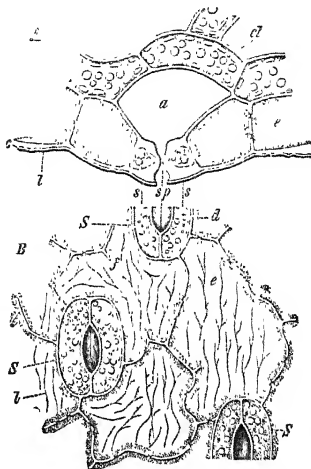


FIG. 32.—Epidermis of *Helleborus*, showing stomata. *A*, in section; *B*, in surface view; *l*, epidermal cells; *c*, cuticle; *sp*, stoma; *ss*, guard cells; *a*, air-chamber; *cl*, mesophyll, or middle portion of leaf.

manner the stem used in 72, and note that the whole of the bundles of both the stem and leaves are stained red.

74.—PRACTICAL WORK TO SHOW THE STRUCTURE OF EPIDERMIS OF LEAF.—Obtain a leaf of the Hyacinth or Lily, and examine the epidermis, as the surface skin is

called. Bend the leaf over the finger of the left hand, so that the under side of the leaf is upwards. Now, with a knife raise the surface skin, and pull off a small piece. Mount it in a drop of water on a glass slide, and examine with the hand lens or microscope. Numerous openings which look like little mouths will be seen, these are the *stomata* (Fig. 32).

75.—PRACTICAL WORK TO ASCERTAIN THE STRUCTURE OF A LEAF.—Place a few leaves of the Box in a five per cent. solution of caustic potash, and boil for fifteen minutes. Empty into a basin, and dissect one leaf. The upper and lower epidermis can be removed, and a middle piece remains. This contains the veins. Mount the various pieces in water, and examine with a hand lens or microscope.

76.—PRACTICAL WORK TO ASCERTAIN THE STRUCTURE OF A SKELETON LEAF.—(1) Search the bottom of a ditch for a rotten leaf, and note that the only portions left consist of the veins. (2) Fill a dish with water, and add to it a few drops of hydrochloric acid. Place a few leaves in the water, and set on a window sill. Change the water every week, and, at the end of a few weeks, all the soft parts have disappeared—only the veins have been able to resist the action of the water and acid.

ARRANGEMENT OF LEAVES ON STEMS.—Leaves bear a definite relation to the stems on which they grow. In the Deadnettle, the square stem carries four rows of leaves, and two leaves grow at one node. This prevents the upper leaves from shading the light from those below. Both the Stock and Wallflower possess five rows of leaves, and the alternate arrangement spreads them out with the same result. The Galium, with its whorled leaves, also separates them, so that each one will receive a due share of light.

It is evident that the arrangement of leaves on a stem must conform to certain general rules, and these will depend upon the distribution of the vascular bundles in the stem.

STRUCTURE OF LEAVES.—A leaf is generally thin, and it exposes a larger surface to light and air in proportion to bulk than stems. If stems are used for support, leaves must be built to expose a large surface to the action of light. A perfect leaf consists of an expanded portion, the blade, a stalk or petiole, and a sheath which clasps the stem. In the Wallflower, both the sheath and petiole are absent, and the leaf is said to be *sessile*. If the blade and petiole are present, the leaf is *petiolate*.

RETICULATE AND PARALLEL-VEINED LEAVES.—All leaves naturally fall into two classes, the reticulate and parallel-veined. The former belong to a group of plants which have the parts of the flower in fours or fives, and the embryo possesses two seed-leaves. Such plants are said to be *Dicotyledons* because of the two seed-leaves. The parallel-veined leaves belong to a different group of plants. Along with such leaves the parts of the flowers are in threes, and only one seed-leaf is present. Such plants are said to be *Monocotyledons*, because of the single seed-leaf.

MINUTE STRUCTURE OF BLADE OF LEAF.—The blade of each leaf consists of an upper and a lower epidermis, and between these comes a portion which is known as the *mesophyll*, or middle of leaf. The lower epidermis is made up of a single layer of cells, and between certain cells minute openings can be seen—the *stomata*. The upper surface is also built of a single layer of cells, and in certain cases stomata may be present. Over the surface of the epidermis a thin layer is converted into a *cuticle*, and this

prevents the entrance of water into the leaf. Hairs may be present on leaves, and these, along with a waxy coating have to do with the protection of the leaf from water and foes. On examining the middle portion of the leaf, it will be found to be composed of an upper palisade, and a lower spongy layer. Between these layers of cells, the veins are arranged. The colour of foliage leaves is due to a green substance which is known as *chlorophyll*, or leaf-green.

SHAPES OF LEAVES.—The size of a leaf depends to a very great extent upon the position in which the plant grows. If plants grow where they are exposed to strong winds and violent storms, the leaves will be small ; on the other hand, plants which grow in sheltered places have large leaves. The student should make out the shapes of leaves, and try and correlate this with the positions in which the plants grow. The figures given in this Chapter will help the student to identify the shapes of leaves.

CHAPTER X

THE FUNCTIONS OF LEAVES

GREEN THE PREVAILING COLOUR OF PLANTS.—A walk along a country lane or through a meadow will be sufficient to show that green is the prevailing colour in plants. Leaves, herbaceous stems, and in some cases the coverings of flowers are green. Even the brown and red sea-weeds which grow along the sea shore, contain the same kind of colouring matter as the leaves of land plants. We will now consider why green is the principal colour found among plants.

77.—PRACTICAL WORK TO SHOW THAT THE GREEN COLOURING MATTER IN LEAVES CAN BE REMOVED.—Obtain some fresh green Cabbage leaves, and place them in methylated spirits. Examine them at the end of twenty-four hours—most of the green colour has disappeared. Now place some of the spirits in a glass vessel, and examine the solution (1) by allowing the light to pass through it, (2) by reflected light. In the former case it appears green, and by the latter red. The green colouring matter is known to botanists as *chlorophyll*.

78.—PRACTICAL WORK TO ASCERTAIN HOW THE CHLOROPHYLL EXISTS IN GREEN LEAVES.—(1) If possible, examine a section of a green leaf with the aid of a microscope. In the cells of the leaf, there will be seen a number of green granules—*chlorophyll granules* (Fig. 33). Each granule consists of a small piece of the living substance of the cell, and this holds chlorophyll in the same way as a sponge holds water. (2) In a similar

manner, examine a section of a leaf which has been kept in methylated spirits for some time. The granules present

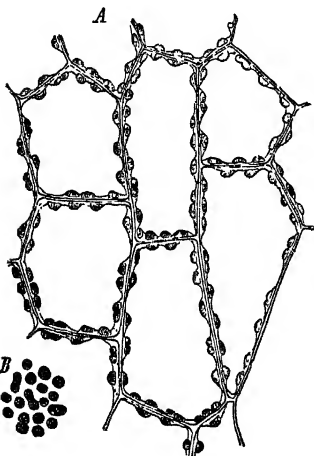


FIG. 33.—Chloroplasts, or chlorophyll corpuscles. *A*, section of cells; *B*, surface view of cells.

in the cells of the leaf will be colourless. This shows that the chlorophyll can be dissolved out of the granules, and that it is soluble in alcohol.

CHLOROPHYLL.

—The green colouring matter of plants is known as chlorophyll, or leaf-green, and it is soluble in alcohol. If the solution is seen by transmitted light, it gives a beautiful green colour, but when viewed by reflected light a deep red colour. The property of a sub-

stance which enables it to give different colours according to how it is viewed, receives the name of *fluorescence*. Such a solution possesses the power of absorbing certain rays of light, and these are converted into heat and energy. In most cases, the chlorophyll is in the form of granules, but in some of the sea-weeds it will be found in bands. For the production of chlorophyll, iron must be obtained by the plant; but strange to say, on analysis, no iron is found in the chlorophyll. It seems that the iron

enables the necessary changes to go on in the plant for its production. The plant must be grown in the light for the production of the green colour. In Experiment*28, the seedlings grown in the dark were pale in colour, but those in the light contained chlorophyll. There are a few exceptions to the general rule stated above; for instance, the cotyledons of Pine seedlings are green even when grown in the dark. We will now consider the functions of the chlorophyll in combination with the living substance of the plant.

79.—PRACTICAL WORK TO SHOW ONE FUNCTION WHICH GREEN LEAVES PERFORM.—(1) Obtain from a gardener a young Cabbage plant, and set it in a large plant-pot. The following experiments can be performed when it has got fairly established. (2) Place the plant in the dark for twenty-four hours. Now remove a leaf, and place it in boiling water for a few minutes. Remove the leaf from the water, and place in methylated spirits for some time. This dissolves out the chlorophyll. (3) Take a piece of tinfoil which will cover one of the leaves, and cut out of it the words **STARCH PRINT**. Now fasten the tinfoil on one of the Cabbage leaves by means of strips of gummed paper. This must be done so that "starch print" is fully exposed to the light. Set the plant on a window sill, so as to expose to bright light for a few hours. Now remove the leaf and place in boiling water. Remove the tinfoil, and bleach in methylated spirits. (4) Place both leaves in a dish, wash in distilled water, and pour on them some iodine solution. There will appear on the one which has been exposed to light the words in blue—*starch print*. On the other hand, the leaf which had been removed after being in the dark for twenty-four hours will not show any blue colour. Why did the portion of the leaf exposed to light turn blue with iodine solution? We will try and discover why.

80.—PRACTICAL WORK TO ASCERTAIN WHAT SUBSTANCE IODINE SOLUTION TURNS BLUE.—(1) Place a small piece of lump sugar in a glass, and pour over it a little iodine solution.¹ It does *not* give a blue colour.

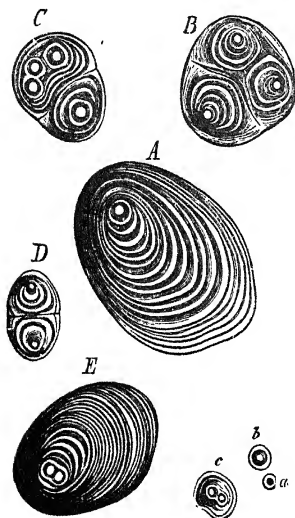


FIG. 34.—Starch grains from the Tuber of Potato. *A*, simple grain; *BCDE*, compound grains; *ab*, young simple grains; *c*, compound grains.

(2) Try a piece of starch. A deep blue colour is the result. (3) Cut a slice from a potato, and pour on it a few drops of iodine solution. Result—the potato turns blue. The potato must contain starch. (4) Perform a similar experiment, using a piece of bread. The result is the same. What conclusions do you arrive at from the above experiments?

81.—PRACTICAL WORK TO ASCERTAIN THE NATURE OF STARCH.—(1) Cut a slice from a potato, and scrape the surface. Place some of the scrapings in a drop of water on a glass slip.

Cover with a cover glass, and look at it with a microscope. A large number of bright-looking bodies will be seen—these are starch grains. They are shaped like cockle-shells.

¹ The iodine solution can be made by dissolving two grammes of iodine of potassium in 100 c.c. of water. Add a few flakes of iodine until no more can be dissolved. Now dilute with water so that it is the colour of sherry.

If the microscope will magnify 300 diameters, the starch grains will present a striated appearance. Figure 34 will make this clear. (2) Boil a little starch in some water. It forms a starch paste. Try and dissolve some starch in cold water. Starch is insoluble in cold water, but a little dissolves when boiled. (3) Add to a little of the starch paste a few drops of iodine solution—a deep blue colour is the result.

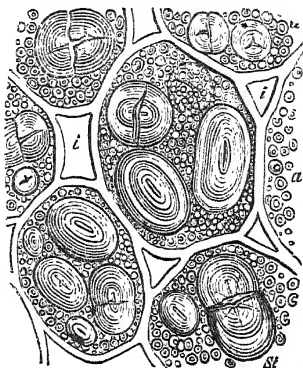


FIG. 35.—Section of Pea seed, showing cells with starch grains in position.

STARCH.—From the above experiments it is perfectly clear—

- (1) That when a green leaf is exposed to light starch is produced.
- (2) That iodine solution turns starch blue.
- (3) That starch is composed of microscopic particles which receive the name of starch grains.
- (4) That starch is *not* soluble in cold water.
- (5) That a little starch is dissolved in boiling water.

COMPOSITION OF STARCH.—From analyses which have been made by chemists it has been discovered that starch consists of the elements carbon, hydrogen, and oxygen. The proportions in which these elements, as they are called, exist in starch will be found below :—

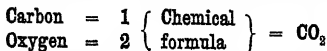
Carbon = 6.

Hydrogen = 10.

Oxygen = 5.

82.—PRACTICAL WORK TO ASCERTAIN FROM WHAT SUBSTANCE IN AIR STARCH IS FORMED.—(1) Plant two Bean seedlings in plant-pots, and when they are firmly rooted perform the following experiments :—(2) Set one plant on a plate and cover it with a bell-jar. Place under the jar a small cup containing a solution of caustic soda. This will absorb one of the gases in the air which is known as carbon dioxide. Expose the plant for a few days to bright sunlight. (3) The other plant must be exposed to the same amount of light, but it must *not* be covered. (4) Remove a leaf from each plant. Place in boiling water; decolourise in methylated spirits; and treat with iodine solution. The leaf from the plant under the bell-jar does not turn blue; that from the normal grown plant gives the reaction of starch. It is evident from the above experiments that the starch is formed from the carbon dioxide in the air.

83.—PRACTICAL WORK TO ASCERTAIN WHAT CARBON DIOXIDE CONTAINS.—(1) Burn a piece of starch in a test-tube until it is converted into charcoal. Empty some of the air out of the tube into another one which contains a little lime-water. Shake; the lime-water turns milky. This is a common test for carbon dioxide. (2) Burn a little sugar in a similar manner. Test the air in the tube with lime-water. Carbon dioxide is present. This shows that carbon dioxide is produced when substances which contain carbon are burnt in air. The carbon dioxide contains :—



84.—PRACTICAL WORK TO SHOW HOW AIR IS SUPPLIED WITH CARBON DIOXIDE.—(1) Place a little lime-water in a test-tube, and by means of a glass tube breathe through the solution. It turns milky. Carbon dioxide must be given out when we breathe. (2) Burn some dry leaves. Test the smoke for CO_2 . Result—lime-water

milky. Carbon dioxide is given out when animals breathe, and it is produced by the combustion of all substances which contain carbon.

CONDITIONS FOR THE FORMATION OF STARCH.—

The starch found in plants is produced by the activity of the living chlorophyll granules. To enable them to perform this useful work, they must be supplied with light, and work at a certain temperature. It is clear from Experiment 79 that this work cannot go on in the dark. The following summary will illustrate the conditions necessary for the formation of starch in the green parts of plants :—

- (1) The green plant must be exposed to light.
- (2) The green plant must be at a temperature of a few degrees above the freezing point.
- (3) The green plant must be supplied with air, so that it can obtain carbon dioxide.
- (4) The green plant must be supplied with water.

85.—PRACTICAL WORK TO ASCERTAIN HOW STARCH CAN BE RENDERED SOLUBLE.—

(1) Take a little starch paste, and place in a test-tube. Add a few drops of iodine solution, it turns blue. Collect a little saliva from your own mouth, and add to the starch paste. Set the tube in a basin of water at the temperature of the body. In one hour the blue colour will disappear, and the solution becomes very thin. This shows that saliva will change starch into another material. What is this material? (2) Dissolve a little grape or malt sugar in water, add to it a little Fehling's solution. Boil. A deep red colour is produced. This is a test for grape sugar. (3) Boil a little starch paste with Fehling's solution. There is no result. (4) Boil some Fehling's solution with a little of the contents of the tube used in No. 1. It gives a deep red colour. This shows that the starch was changed into sugar by the saliva. (5) Grind up a little malt, and cover it

with a little milk-warm water. Let it stand for a few hours. (6) Now add to some starch paste a little of the extract of malt obtained in No. 5. Keep at temperature of the body for an hour. Test with Fehling's solution, sugar is present.

HOW STARCH IS CHANGED INTO SUGAR.—Seeds contain a substance which changes starch into sugar, and a similar change can be produced by saliva. How does sugar differ from starch? Grape sugar contains the same elements as starch. The following table illustrates the difference :—

	Carbon.	Hydrogen.	Oxygen.
Starch . . .	6	10	5
Grape sugar . .	6	12	6

This shows that the only difference is that the grape sugar contains a little more hydrogen and oxygen—in fact, the same amount as exists in water. The addition of water to the starch will be sufficient to change it into grape sugar. Most parts of plants contain a ferment which can produce this change.

STARCH A RESERVE MATERIAL.—Starch is stored up in seeds, stems, and roots for future use. When the embryo in an albuminous seed begins to grow, the ferment present changes some of the starch into sugar, and this passes into the embryo. The young plant lives on the substances stored up in the seeds. Experiments 79 and 82 prove that starch is formed in green leaves. Such starch is converted into sugar, and removed from the leaf. From these considerations, we come to the conclusions that starch is formed by the green portions of a plant, and this when changed into sugar feeds the plant.

SUGAR.—The first substance which a green plant forms out of carbon dioxide and water is sugar, and this is subsequently converted into starch by the action of the chlorophyll corpuscles and other similar structures.

CHAPTER XI

PLANTS AND THEIR FOOD

PLANTS AND THEIR FOOD.—It is reasonable to suppose that those plants which have their roots fixed in the soil, will obtain the water and minerals required for their growth from the medium in which they live (Experiment 64). This will hold good for most plants which live in the soil, but there are exceptions to this rule, for numerous plants have special means of obtaining food. This enables botanists to classify plants into classes according to the peculiarities which they exhibit in searching for, and absorbing nutritive materials. The outline classification given below will illustrate the different classes into which plants can be naturally divided by this means.

CLASSIFICATION OF PLANTS BASED ON METHODS OF OBTAINING FOOD.

- (1) Land plants, which live in the soil.
- (2) Water plants, which live in the water.
- (3) Amphibious plants, which can live either in or out of water.
- (4) Rock plants, which live fixed to rocks.
- (5) Parasitic plants, which live in or on a host plant.
- (6) Saprophytic plants, which live in decomposing organic matters.
- (7) Carnivorous plants, which obtain some of their food from small animals which they entrap.
- (8) Symbiotic plants, where two plants live together, and form one individual.

LAND PLANTS.—We will now proceed to find out how land plants obtain the carbonaceous food, water, and minerals they need for their full development.

CARBONACEOUS FOOD.—In working through Chapter X, we noticed that green plants take from the air carbon dioxide, and use it to form sugar and starch. The green foliage leaves are the principal organs by which plants collect their carbonaceous food, as the carbon dioxide may be called, and this passes in by the stomata. Even though the carbon forms nearly one-half of the dry weight of a plant, there still remains the mineral matter and water to account for.

WATER.—There is no great difficulty in accounting for the water which a land plant requires for its growth. It can be stated that nearly the whole of the water which a plant absorbs comes from the soil. Most of this reaches the soil in the form of rain, and a smaller portion as dew and snow. In many parts of the world rivers overflow their banks, and by this means supply the soil with much of the water they contain. The people who live in certain districts imitate the action of rivers by constructing channels along which they allow water to flow, and by irrigation, as it is called, several crops can be obtained from one plot of land during a single season.

MATERIALS IN SOILS.—The student should turn back to Experiments 64, 65, and 66 to ascertain what soils contain. In addition, it can be said that the soil is the raw material from which plants obtain water and minerals. We will now proceed to more thoroughly examine the soil, and its work in connection with plant life.

86.—PRACTICAL WORK TO ASCERTAIN WHAT SOILS ARE COMPOSED OF.—(1) Obtain a quantity of good garden soil, and examine it. This can be done by passing some of it through a coarse sieve so as to separate

the larger pieces. If a still finer sieve, or better still a series of sieves of different sizes can be obtained, the soil can be separated into grades which are characterised by the size of their particles. By this method it will be seen that good garden soil consists of small stones, the remains of the roots and stems of plants, and very fine material. (2) Place some of the finest material in a glass of hot water. Stir well, and let it stand for five minutes. Now pour off the water into another glass. Note that some of the finest material is suspended in the water. Repeat the washing until the water which is poured off is quite clear. If the soil is washed several times there will remain behind in the tumbler only very small stones and sand. (3) Perform similar experiments, using sand, clay, lime and vegetable soil.

From the observations made in performing the above experiments, it will have been noticed that soils contain, as a general rule, the following ingredients:—

Stones.	Vegetable matter.	Clay.
Sand.	Lime.	

87.—PRACTICAL WORK TO ASCERTAIN THE CHARACTERS OF THE ABOVE INGREDIENTS.—(1) Mould a little ordinary sand with water, and set on one side to dry. (2) In a similar manner treat some modelling clay. Examine them when dry, and note that the sand is very friable or is easily broken, but the clay is hard and requires some force to break it. (3) Now mix equal quantities of sand and clay together, and mould into a block with the aid of water. Allow the block to dry. The clay will be seen to unite the sand, or to act the part of a cement. (4) Try and mould the stones into a block as in No. 1, and with clay as in No. 3. How do they act? (5) Dry, and burn some of the vegetable matter which was separated by the coarse

sieve from the garden soil. A fine ash will form the residue, for nearly all the constituents of the vegetable matter can be burnt off.

88.—PRACTICAL WORK TO ASCERTAIN WHICH INGREDIENTS HOLD THE MOST WATER.—Weigh or measure a given quantity of dry sand, clay, and vegetable matter which has been separated from garden soil. Place in vessels, and pour an equal quantity of water on each. Let them stand for half an hour, and note which has soaked up the most water.

89.—PRACTICAL WORK TO ASCERTAIN WHAT VEGETABLE MATTER CONTAINS.—Allow some vegetable matter to decompose, and pass through it some distilled water. Now apply the test given in Experiment 66 to the solution obtained. What is the result? It shows that by the decomposition of plant-remains, compounds containing nitrogen are set at liberty.

90.—PRACTICAL WORK TO ASCERTAIN THE PART PLAYED BY LIME IN A SOIL.—(1) Drop a little weak hydrochloric acid (1 of acid to 4 of water) on a piece of limestone or raw chalk. It effervesces. This shows that carbon dioxide escapes when chalk or limestone is treated with an acid. (2) Treat some garden soil with hydrochloric acid. Does it effervesce? If it does, it probably contains carbonate of lime.

SOILS CONTAIN IN ADDITION TO SAND, ETC., LIME.—From the above experiment, it seems probable that all fertile soils contain carbonate of lime. Both chalk and limestone consist of carbonate of lime. If either of them are burnt in a lime-kiln, the following change is the result:—

Carbonate of lime when acted on by heat = Quick-lime
+ Carbon dioxide.

The carbon dioxide is driven off as a gas, and the quick-

lime is left behind. If water is added to the quick-lime, there is a certain amount of heat produced, and slacked lime is the result. When this is allowed to stand for some time exposed to air, it absorbs carbon dioxide, and forms carbonate of lime once more. But it possesses different properties to the chalk or limestone, it breaks up to form a powder or is very friable, and can easily be mixed with the soil.

THE WORK DONE BY LIME IN SOIL.—Lime in a soil performs several important functions, which are enumerated below.

- (1) The lime in a soil coagulates the clay and makes it friable.
- (2) The lime neutralises any acid which the soil may contain, and sweetens it.
- (3) The lime acts as a plant food.

91.—PRACTICAL WORK TO ASCERTAIN THE FUNCTIONS OF LIME IN A SOIL.—(1) Mix up a little clay with a large quantity of water until most of the clay is suspended in it. (2) Nearly fill two tumblers with the liquid. Now pour into one a little distilled water, and into the other the same quantity of lime-water. Note the action of the distilled water and the lime-water in producing precipitation of the sediment. The liquid to which the latter material has been added will clear the quickest.

THE PART PLAYED BY THE VARIOUS INGREDIENTS OF SOILS IN THE GROWTH OF PLANTS.—From the experiments performed, it seems clear that each ingredient in the soil plays a most important part in the growth of plants. The sand helps to open up the soil; this makes it easier for the roots of plants to penetrate, and it allows both water and air to enter between the particles of soil. On the other hand, the clay and sand gives

support to the plant and firmness to its roots. The clay also contains certain minerals which the plant requires for food. Both the clay and humus hold water, and this can be absorbed or taken in by the roots of plants. The vegetable matter, when it decomposes, sets at liberty compounds, such as nitrates, which plants can utilise for their growth. Stones play the same part in a soil as sand, and when they are broken up help to form finer materials which are so necessary for the growth of plants. Lime coagulates the clay, and enables a fine tilth to be produced for the germination of seeds and the subsequent growth of the seedlings. A fine tilth is produced when the soil is very friable. Lime also supplies to plants one of the necessary elements of growth.

HOW SOILS ARE FORMED.—The rocks which make up the outer portion of the earth are broken down by the action of rain, running water, frost, wind and numerous other agents to form soils. If limestone is near the surface, it is broken up by the agents enumerated above, and a lime soil will be produced. This is also true of sandy and clayey soils, the former being formed from sandstones and the latter from shale, granite, or similar rocks. Such soils can be said to be formed *in situ*, because they were formed in the position in which they are found. Vegetable soils, such as peat, grow, and they contain large quantities of plant food, but it is generally in an unavailable form. If the materials in the soil are exposed to the action of lime and oxygen, the unavailable plant food is made available. Rivers deposit materials along their banks, especially when they flow slowly, as in the lower reaches. This forms loam and alluvial soils, and they receive the name of *transported* soils, because their ingredients have been carried by water.

PARTS PRESENT IN SOILS.—If the student examines

a section or exposure showing the soil and its associated structures, as in a quarry or when a trench is opened up for drainage purposes, the following layers will be seen :—

(1) *Soil*. This layer is on the surface, and it varies in thickness from six inches to three feet, and is generally darker in colour than the subsoil.

(2) *Subsoil*. This consists of coarse material, and it passes down into solid rock.

(3) *Rock*. This is always being drawn upon to form subsoil.

COLOUR OF SOILS.—The colour of a soil depends upon the proportion of the different ingredients present. A dark garden or meadow soil is rich in humus; in fact, the large quantity of vegetable matter present gives the characteristic colour. Red soils contain a large quantity of iron, and light-coloured ones consist principally of sand or chalk. The student should make observations on the mode of formation and the characters of soils in his own district.

PLANT FOOD IN SOILS.—The characters of a soil influence to a great extent the growth of plants. Not only do the physical characters of soil, such as cohesion, colour, and proportion of vegetable matter influence the plants, but the composition of the ingredients act on their growth. We will now determine what plants require for their growth.

92.—PRACTICAL WORK TO ASCERTAIN THE FOOD REQUIRED BY PLANTS.—(1) Obtain a quantity of fine sand, and boil it in water for several hours, so as to remove any plant food it may contain. To make certain that the whole of the plant food is removed from the sand, change the water every half-hour during the boiling process. (2) Now place the sand in an old saucepan, and set it on the fire until it is red. Let it cool, and use in the following

manner. (3) Place crocks (broken pots) for drainage into four plant-pots, and nearly fill each with the cool sand. (4) Plant in each pot a well-developed seedling, and water well with distilled water. Now number the pots, and supply them with food in the following manner: (i) Feed No. 1 with the solution given on p. 36. This contains everything that the plant requires for its growth, and is said to be a normal solution. (ii) Supply No. 2 with a solution which contains everything found in the normal solution except saltpetre. (iii) No. 3 should receive a similar solution to No. 1, but leave out the phosphate of lime. (iv) Give to No. 4 distilled water. (5) Note how they grow, and at the end of two months prepare a series of notes to describe the results obtained.

ELEMENTS IN PLANT FOOD.—For the perfect growth of green plants, ten essential elements are necessary. These are given below in the form of a table:—

ELEMENTS.	HOW ABSORBED.	FROM WHAT SOURCE OBTAINED.
Carbon . .	By green parts only .	The carbon dioxide in the atmosphere.
Hydrogen .	By root-hairs . . .	The water in the soil.
Oxygen .	" " . . .	The water in the soil.
Nitrogen .	" " . . .	The nitrates in the soil.
Sulphur .	" " . . .	The sulphates in the soil.
Phosphorus	" " . . .	The phosphates in the soil.
Potassium .	" " . . .	The potassic salts in the soil.
Calcium .	" " . . .	The carbonates in the soil.
Magnesium	" " . . .	The carbonates in the soil.
Iron . . .	" " . . .	The compounds of iron in the soil.

Plants absorb in addition to the elements enumerated in the above table, silicon, sodium, and chlorine. These elements may not be necessary for the growth of plants, but they are taken in with the water.

PLANTS MUST HAVE THEIR FOOD IN THE FORM OF COMPOUNDS.—It seems probable that all plants take their food in the form of compounds. Even the nitrogen of the atmosphere cannot be utilised by plants, and it must be obtained in a combined state. In the soil numerous compounds exist, and these are utilised by the plants when in solution. The root-hairs and newer portions of the roots take in the very weak mineral solution from between the particles of the soil. Plants have to take in very large quantities of water on purpose to obtain all the materials they require, and the excess passes out of the plants by the stomata as aqueous vapour (p. 123).

CHAPTER XII

PLANTS AND THEIR FOOD (*continued*)

WATER PLANTS.—Only a comparative few plants live entirely covered with water, such as sea-weeds, spirogyra, elodea, and a few flowering plants. These are known as water plants. Even if the roots of a flowering plant which lives in water are embedded in mud, it will be in contact at every point with water, and its roots, stem, and leaves are surrounded with it. It will be necessary for us to discover if water plants differ in structure from land plants; and from the results obtained to draw correct conclusions as to how they obtain their food.

93.—PRACTICAL WORK TO ASCERTAIN THE STRUCTURE OF WATER PLANTS.—Obtain one of the large sea-weeds, such as *Fucus*, which may be found floating in the sea or attached to the rocks in rock pools along the sea shore. (1) Try and bend it; this can be easily done. It differs in this respect very much from woody or shrubby flowering plants, and more nearly approaches the herbaceous ones. Cut across it; no vascular bundles will be seen. It differs from nearly all the flowering plants which live on the land in having no vascular bundles to give strength and conduct water. Examine the outer layer. It differs from the covering of land plants in having no cuticle, as the outer layer of the epidermis is called, and nothing like stomata can be seen. At the base of the plant will be seen a sucker or disc, by means of which it was attached to a rock, or to an animal like a crab. This can be compared to a root of a flowering

plant which fixes it firmly in the soil, but differs from it in possessing nothing like root-hairs. (2) Place a piece of the plant in methylated spirits for twenty-four hours. A green liquid is produced. This is a solution of chlorophyll (p. 75). The brown colouring matter in the sea-weed masked the green colour (p. 76). (3) Examine in a similar manner the structure of a flowering plant which lives in water; the Water Crowfoot will be a good example.

HOW WATER PLANTS DIFFER FROM LAND PLANTS.

—Water plants, such as sea-weeds, and a number of flowering plants, differ in structure from land plants in many important particulars. The most important of these are shown below in the form of a table.

WATER PLANTS DO NOT POSSESS—	LAND PLANTS DO POSSESS—
A cuticle, but a slimy layer may cover the epidermis.	A cuticle.
Stomata.	Stomata.
Well-developed vascular bundles.	Well-developed vascular bundles.
Root-hairs.	Root-hairs (a few exceptions).

Water plants have no use for stomata, for the gases pass into the plants along with water, and, as they give out no aqueous vapour, such structures would be of no service. A cuticle would prevent the passage of water into the plant, and so the structure is absent. Root-hairs are organs which enable land plants to absorb their food from the soil. They are absent from water plants, because the water can enter any portion of the plant, and they do not require any special organs to absorb water and minerals. The vascular bundles found in land plants help to give strength to the plant, and conduct water from the roots to the leaves. Water plants are supported by the water, and

strong vascular bundles are not required for that purpose ; only weak ones being formed. Conducting channels can serve no useful purpose in their economy, as water can enter at all points of the plant.

Conclusions.—The whole of the food which a water plant requires for its growth is obtained from the water in which it lives, and the necessary minerals and carbon dioxide can pass into the plant along with the water.

AMPHIBIOUS PLANTS.—Plants like the Water Crowfoot have some of their leaves submerged in water, while some float on the surface. All plants which possess both floating and submerged leaves are amphibians, and they can live either in or out of water. For should the water dry up in which they live, only the submerged leaves die ; the floating ones live on and prevent the death of the plant. Submerged leaves are generally finely divided, but the floating ones are larger.

94.—PRACTICAL WORK TO ASCERTAIN THE STRUCTURE OF AN AMPHIBIOUS PLANT.—Try and find the Water Crowfoot. It lives in ponds, and its white flowers can generally be seen above the surface of the water during April, May, and June. Examine it. The floating leaves are orbicular or reniform, while the segments of the submerged spread in all directions. Do the stems contain a well-developed vascular system ? Examine the roots and try and find if root-hairs are present.

ROCK PLANTS.—It is a common sight to see on a bare face of rock, perhaps on some mountain slope, a rich covering of mosses, liverworts, and lichens. Old walls are often covered with beautiful orange-coloured lichens, and numerous rock plants can be found growing at an altitude of thousands of feet above the sea-level in the Alps. All plants which are fixed to rocks can be called rock plants. How do such plants obtain their food ? Most persons would say :

Why, from the rocks to which they cling. It seems probable that this is far from the truth. Rock plants may grow on rocks which cannot supply them with a single mineral constituent which they require. Pure white quartz often possesses a rich covering of plants, but they cannot utilise this substance for food. Most of the water and minerals which these plants need for their existence comes from the dust which falls upon or is brought to them by rain, dew, and snow. Plants of this description contain chlorophyll, and this enables them to use carbon dioxide to form sugar and starch. The student should examine as many examples of rock plants as possible, so as to be able to recognise them at a glance. He may also find similar plants growing on the bark of trees; they only cling to the bark for support, and take nothing from the plants on which they live.

PARASITIC PLANTS.—Just as we find that social

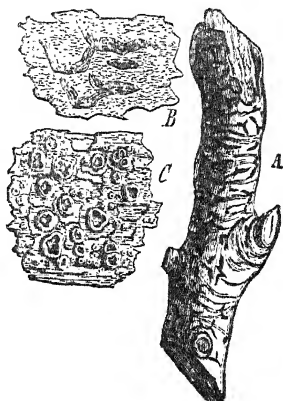


FIG. 36.—Lichens slightly magnified.

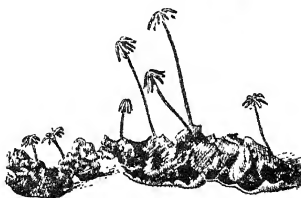


FIG. 37.—Plants of Liverworts fruiting.

parasites prey on society, so in the plant world numerous plants live at the expense of other plants or animals. A parasitic plant is one that lives in or on another plant, and takes from it either the whole or some of the materials which are necessary for its nutrition. The plant or animal on which it lives is known as the *host*. The following table gives a simple classification of parasites :—

PARASITIC PLANTS CAN BE DIVIDED INTO—

FLOWERING PLANTS.		NON-FLOWERING PLANTS.	
Wholly Parasitic. <i>E. g.</i> Dodder.	Partially Parasitic. <i>E. g.</i> Mistletoe.	Multicellular Fungi. <i>E. g.</i> Pithium.	Unicellular Fungi. <i>E. g.</i> Bacteria.

PARASITIC FLOWERING PLANTS.—The flowering plants which have adopted the parasitic habit fall naturally into classes ; these are : (1) Those which obtain from the host everything they require for their nutrition. (2) Those which only obtain a portion of the necessary food from the host plant. The plants belonging to the former class have no chlorophyll, but the latter possess it. Green parasites obtain a portion of their carbonaceous food from the air, but it stands to reason that the plants without chlorophyll must take the whole of the food for their growth from some other source.

PARASITIC FLOWERING PLANTS WITHOUT CHLOROPHYLL.—If a number of the gorse bushes which grow so abundantly in most parts of the country are carefully examined during summer, they will often be found to have twining round them slender pale-coloured filaments, which look much like narrow pieces of tape. When a piece of material is examined more closely, there will be seen on the side nearest to the gorse stem, small suckers by which

the filaments cling to the plant. There may also be seen during the flowering season, numerous bunches of flowers (flowers from July to September). This plant is the Dodder. The Dodder may be found growing on Nettles, Clover, Ling, Vetches, Thyme, and other suitable hosts.

95.—PRACTICAL WORK TO ASCERTAIN THE STRUCTURE OF THE DODDER.—Obtain a piece of Dodder which is still attached to a portion of the host, and notice : (1) The colour, it may be white, pink, or yellow. (2) The plant is without leaves, but numerous heads of flowers may be present. (3) The stem is not much thicker than twine. (4) Using a lens, note the suckers which penetrate the host, and by means of which nutritive materials are drained from it. (5) Now cut across both the stem of the host and that of the Dodder. Examine the cut end with a good lens. The sucker will be seen enclosed within the stem of the host.

HOW THE DODDER FINDS ITS WAY INTO THE HOST.—The seeds of the Dodder either fall or are blown from the fruits, and fall on the soil. Here they remain until the following spring, when they germinate. Dodder seeds are very small, and do not contain an embryo like that of the Bean, but still they produce a seedling when they germinate. When the seed germinates, a tiny filament is produced, this begins to move round in a circle. If the filament comes in contact with a portion of a plant, it twists round it, suckers being formed at the point of contact. Growth takes place at the end of the filament or stem ; thus the whole of the plant, and in some cases the surrounding ones become infested with the parasite.

The Broom-rape is another well-known example of a leafless parasite. It is brownish in colour, and produces a tuberous root. The flowers, which grow on spikes or racemes, are produced from June to August, and they can

often be found standing just above the level of the soil. Another fleshy-root parasite is the Toothwort, which attaches itself to the roots of the Hazel, and flowers from April to May. Space will not permit of a fuller treatment of this interesting subject, and the student must consult more advanced books which deal with parasites.

PARASITIC FLOWERING PLANTS WITH CHLOROPHYLL.—The well-known mistletoe is a good example of a parasite which is green. It is very common during Christmas festivities, and can then be obtained for examination.

96.—PRACTICAL WORK TO DETERMINE THE STRUCTURE OF THE MISTLETOE.—Obtain a specimen of the Mistletoe while still attached to a portion of the host plant. The host plant may be the Apple, Fir, Poplar, and in rare cases the Oak. Now examine the specimen, and notice : (1) It is an evergreen shrub. (2) The leaves are either in pairs or in threes, and the stem on which they grow may be jointed. (3) Numerous white berries may be present. (4) Examine a fruit and the seeds. The seed is protected by a hard covering.

The seeds of the Mistletoe are scattered by birds, and they can pass through the food canal without undergoing any change. When favourable conditions arise, the seed germinates and the root which passes out enters the host plant. The tree grows, and buries the numerous roots which are given off from the stem of the Mistletoe. If the student can examine a section through the stem of the apple which has the Mistletoe attached, the difference in the colour will enable the student to distinguish where the roots are buried.

ROOT-PARASITES.—Many plants which appear harmless to the ordinary observer when they are carefully examined

will be found to be fixed to the roots of other plants. The Bastard Toad-Flax which grows in dry chalky pastures possesses fibrous roots, and these are attached to the roots of other plants. If such a plant is removed from the soil and its roots are examined, small white suckers will be seen on them. The suckers can enter the roots of the plants which grow round the parasite, and the poor condition of many of the plants from which they draw nourishment, clearly shows the deadly nature of their action. The following list mentions some of the common root-parasites which possess green leaves.

NAME OF PLANT.	WHERE IT GROWS.	FLOWERING PERIOD FROM—
Eyebright.	Meadows and heaths.	May to September.
Yellow-Rattle.	Wet places.	May to July.
Lousewort.	Marshes and bogs.	May to September.
Cow-Wheat.	Heaths and pastures.	June to September.
Bastard Toad-Flax.	Chalky pastures.	May to July.

Green parasites take from the host plant water and minerals, but are able to utilise the carbon dioxide in the air as carbonaceous food. Some botanists have suggested that such plants may even transfer carbon compound to the host plant.

NON-FLOWERING PARASITES.—Many of the diseases of both animals and plants are caused by plants which are destitute of chlorophyll, and belong to a group of plants which are known as *Fungi*. In this case, as in that of the Dodder, the whole of the food is obtained from the host. They can be divided into unicellular and multicellular forms. The former consists of only a single cell, and they are very minute. They reproduce by division, and some forms have been seen to reach their full growth in the space of twenty minutes, when they divide into two. In this way a single

plant begins to grow, and its offspring at the end of a few days may be many millions. It is this rapid increase in number which may make them so dangerous to health. The latter are made up of above one cell, and for this reason they are said to be multicellular.

Bacteria.—The unicellular fungi which produce disease are known as bacteria. They are very minute, as we have seen, but “what they lack in size they make up in number.” Bacteria live in air, water, food, on and in animals and



FIG. 38.—Fructifications of a multicellular fungus.

plants. Some of them are our friends, and others are our foes. Decomposition of organic matter is due to them, and they produce nearly all bad smells. Nitrification or the production of nitrates, which plays such an important part in the fertility of soils, can only go on where certain kinds of bacteria are present. Consumption, diphtheria, typhoid, cholera, and numerous other diseases from which the human race suffer are due to special bacteria. It is of great importance to all, that a fuller knowledge of the life of these organisms should be obtained, so that the above diseases can be stamped out.

Multicellular Fungi.—Many of the multicellular forms live on plants, and such well-known plant diseases as bunt in wheat, potato disease, and the “damping off” of seedlings are the results of their living activity.

SAPROPHYTIC PLANTS.—All plants which obtain carbonaceous food from decomposing organic matters are Saprophytes, e.g. Mushroom, Toadstool, and Yeast. The multicellular forms produce roots or suckers which enter the decomposing matter, and complex carbon compounds are absorbed. The Yeast plant can live on sugar, water, and minerals. Each Yeast plant does not exceed the $\frac{1}{3000}$ part of an inch in diameter, and some are so small that 7,000 placed edge to edge will not cover the space of one inch. A few British flowering plants are Saprophytes. The well-known *Monotropa*, or Bird's Nest, and the Bird's Nest Orchis are good examples.

CARNIVOROUS PLANTS.—In damp places and on the moors of England, Ireland, Scotland, and Wales, numerous plants live which have the power of entrapping insects, and using them as food. The Sundew is a small plant which possesses a rosette of leaves which rest on the ground, and on the leaves numerous hair-like bodies exist. These receive the name of tentacles, and the swelling at each tip is a gland. If the Sundew is examined on a bright sunny day, each gland appears to have on it a drop of dew, and the numerous drops give to the plant a very peculiar appearance. A small fly approaches, and touches a tentacle, the shiny sticky drop of material which looked like dew holds it tight. As the fly struggles, other tentacles bend down towards the struggling animal, and at last they cover it up. The glands pour out on the fly a digestive juice, and all the nutritive materials are dissolved out. At the end of a week, the leaf relaxes, and it is ready for some more food.

The Butterwort also possesses a rosette of leaves, and these are of the colour of butter. Each leaf is turned up at the edge, and is very sticky. In most cases, dead insects will be seen on the leaves. Both living and dead insects come in contact with the leaves, the former accidentally, and the latter reach the plant by the action of

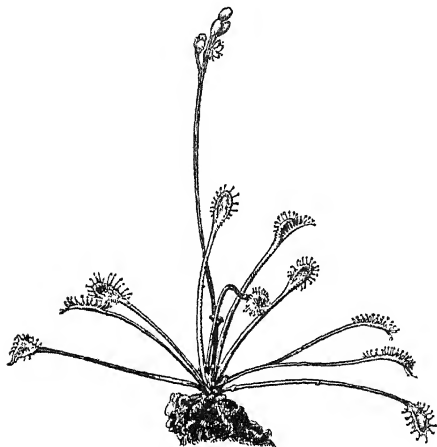


FIG. 39.—The Sundew, a carnivorous plant which grows on the moors, and in damp places. The leaves are sticky, and sensitive to touch.

the wind. The sticky material on the leaves seems to have the power of digesting animal matter; there is no doubt that compounds of nitrogen, and perhaps carbon compounds, are absorbed in this way.

The Bladderwort grows immersed in water, in slowly-flowing rivers, ponds, and tarns. Small bladders are attached to the long slender stems, and if these are

examined, numerous stiff hairs will be seen standing out near a tiny trap door. The interior of the bladder is richly supplied with large stellate cells, and these are supposed to be absorbing organs. Numerous small animals live in the water, and some of these push up against the small door which leads into the bladder. It is so easy to enter, but they can never return, for the door only opens inwards, and after a struggle to regain liberty the animals die. Their decomposing bodies give up food materials which the stellate cells absorb.

All carnivorous plants live where nitrogen compounds are very scarce, and they make up for the lack of this by entrapping small animals. These decompose, or are digested, and the organic compounds can be utilised for food. Most of them contain chlorophyll, and they can utilise the carbon dioxide as a source of carbonaceous food.

SYMBIOTIC PLANTS.—Social reformers have long had the hope that a time will come when every individual in the community will do his due share of work, an ideal state of society being the result. The day has still to come for the human family, but a few plants have solved the problem, and live in communism, mutualism, or Symbiosis. Plants like Peas, Beans, Vetches, and Clover have a remarkable way of obtaining nitrogen. If any of these plants are removed from the soil, there will be found on the roots small tubules or root nodules. It has been ascertained by microscopic examination that the root tubercles contain bacteria. The bacteria enters the root hairs, and this stimulates the living substance so that tubercles are produced. For a long time farmers and gardeners have known that manures containing nitrogen did not help the growth of leguminous plants (such as Clover, etc.) to any great extent. Botanists by systematic research have discovered that the bacteria can use the free

nitrogen of the atmosphere, and produce from it compounds of nitrogen which are given up to the green plant. Most likely, the leguminous plant gives up to the bacteria carbon compounds. This is a case of symbiosis.

The lichen (p. 94), is a compound plant, for an alga (seaweed) and a fungus live together. By careful examination, it has been ascertained that the filaments of the fungus surround the cells of the alga. The fungus takes up water and minerals, and hands some of these up to the alga; the alga containing chlorophyll, is able to build up carbon compounds from the carbon dioxide of the air, and passes some of this on to the fungus. The alga and the fungus live together, and form a symbiotic plant.

If the roots of the Hazel, Oak, Heath, Beech, and Rhododendron are examined, they will be seen to be closely invested with a fine network of filaments. These belong to different kinds of fungi, and all the observations made seem to point to the fact, that the filaments take from the soil substances which they pass on to the roots of the plant around which they live. There is reason to suppose that this is a case of symbiosis. The young seedlings of the Oak, etc., cannot be raised in pure sand, even if they are fed with a normal culture solution. Why? The filaments act as absorbing organs, and if these are absent, even if the plant is surrounded with food materials, it may die of starvation.

A similar partnership is found to exist between the Bird's Nest (*Monotropa*) and the filaments of a fungus. In fact, the fungus flowering plant can only grow when living in symbiosis with the non-flowering fungus.

CHAPTER XIII

WHAT PLANTS DO WITH THEIR FOOD

SUBSTANCES FOUND IN PLANTS.—If suitable means are used for their detection, substances can be found in plants, such as sugar, starch, cellulose, fat, and protein. It is evident that these substances did not exist in the food they absorbed from the soil and air. Where did they come from? They must have been made by the plants from their food. In Chapter X, we noticed that if a green plant was supplied with water and carbon dioxide, it could make from them, during sunlight, sugar; the sugar generally being converted into starch. This process is known as carbon assimilation or photosynthesis, and it is probably the starting-point of a large number of transformations which go on within the plant. In fact, the plant is like a workshop within which raw materials are converted into the finished products. The raw materials which a plant absorbs, consists of water, minerals, and carbon dioxide. From these, the living activity of the plant forms the substances enumerated above. We will now consider the characters of the most important substances which can be detected in plants, and their formation.

97.—PRACTICAL WORK TO ASCERTAIN THE CHARACTERS OF STARCH.—The student should once more perform the experiments given in Experiment 81, so as to confirm the inference drawn as to the characters of starch. In addition to this, he should read the conclusions as to the characters and composition of starch which are given on p. 79.

98.—PRACTICAL WORK TO ASCERTAIN THE CHARACTERS OF CELLULOSE.—(1) Place a little cotton wool

in a clean dish or on a glass slide, and add a drop of iodine solution. It stains faintly yellow. Now add to it a drop* of sulphuric acid. The cotton changes to a deep blue-black colour. This is the test which is generally used for the detection of cellulose. (2) Boil a little cotton wool in a test-tube with water, it undergoes no change. It differs from starch (i) because it does not turn blue with iodine solution alone, but sulphuric acid must be added to it. (ii) Starch when boiled forms a paste, but cellulose undergoes no change. (iii) Cotton is nearly pure cellulose. (3) Scrape from the surface of a Date stone the brown covering, there will come into view a substance which looks like ivory—this is cellulose. Apply the tests used in the case of cotton.

99.—PRACTICAL WORK TO ASCERTAIN THE CHARACTERS OF THE DIFFERENT KINDS OF SUGAR.—

(1) Obtain a little Fehling's solution. This is used as a test for certain kinds of sugar which are known as reducing sugars, because they can reduce copper oxide. That is, they have the power of extracting from an oxide, like the one mentioned above, oxygen, and the metal is thrown down. (2) Squeeze into a test-tube a little juice from a grape. Add to it some Fehling's solution, and boil. It turns yellowish-red. (3) Place a piece of ordinary sugar in a test-tube, add water, it dissolves. Now add a little Fehling's solution, and boil. There is no change in colour. (4) It seems evident that there must be a difference between the sugar as it exists in grapes and ordinary table sugar. All sugars which have the power of giving a yellowish-red colour when boiled with Fehling's solution are *reducing* sugars, and those which remain unchanged are *non-reducing* sugars. Grape and malt sugars belong to the former, and cane or ordinary sugar to the latter.

100.—PRACTICAL WORK TO ASCERTAIN THE CHARACTERS OF FATS.—(1) Obtain a little linseed oil, and place in a test-tube. Add to it a few drops of osmic acid, it turns black. This is the common test for fats. (2) Shake up some linseed oil with a little solution of common soda. It turns milky. The oil is emulsified. (3) All fats turn black in the presence of osmic acid, and are emulsified if shaken up with an alkaline solution.

101.—PRACTICAL WORK TO ASCERTAIN THE CHARACTERS OF PROTEINS.—(1) Mix a little white of egg with water, and place some in a test-tube. Boil. The white of egg is coagulated, and forms a white solid. (2) Add to a little of the solution a few drops of nitric acid, and boil. The coagulated white of egg turns yellow. Cool under a stream of water, and add a little solution of ammonia. An orange colour is produced. (3) White of egg contains a protein. All proteins are coagulated by heat, and give the characteristic colour test as shown above. Perform the following experiments in a similar manner. (4) Apply the colour test for proteins to some of the material from the interior of a grape. Do grapes contain proteins? (5) Place a little flour in some water in a test-tube, and apply the colour test. Are proteins present in flour? (6) Soak some barley seeds in water for a few hours, and then grind up in a mortar. Test a little for proteins. What is the result?

CLASSIFICATION OF PRODUCTS.—The following classification shows at a glance the relationship of the common substances found in plants :—

Nitrogenous (containing nitrogen). *Non-nitrogenous* (without nitrogen).

Proteins.
Albuminoids.

Fats.
Carbohydrates.

THE PROTEINS.—Nearly all substances which contain carbon, hydrogen, oxygen, nitrogen, and sulphur are said to be proteins. They are necessary for the growth of plants and animals. Green plants can build them up from carbon dioxide, water, nitrates, and compounds of sulphur. Plants without chlorophyll must have a carbon compound to start with, and this, along with water, nitrates and sulphur compounds, can produce proteins. Legumin and gluten are forms of proteins found in plants.

THE ALBUMINOIDS.—The albuminoids are more difficult to understand, and the student must consult a more advanced book for a description of these compounds.

THE FATS.—The fats contain carbon, hydrogen, and oxygen. If one gram of fat is burnt it will produce 9.41 calories of heat, but the same amount of either sugar or starch only produces 4.1 calories. Fats are found in seeds and fruits, *e.g.* castor-oil seed, linseed, almond, and the fruit of the Olive.

THE CARBOHYDRATES.—All the substances which plants produce, and which contain carbon, hydrogen, and oxygen, the hydrogen and oxygen being present in the same proportion as in water, are classified as Carbohydrates; *e.g.* sugar, starch, cellulose, and gum. They are among the simplest of the compounds formed by plants, and sugar at least, is the starting-point for nearly all the compounds which plants produce.

HOW THE ABOVE COMPOUNDS ARE FORMED.—It must be distinctly understood that plants form various compounds which we have considered because they are endowed with what we call life. The living (*vital*) principle which all living plants contain is associated with a substance known as protoplasm. The table given below is an attempt to state the probable way in which certain compounds are formed. It does not pretend to be

absolutely correct, and it will probably require revising as new discoveries are made.

COMPOUND.	FORMED—	CONDITIONS NECESSARY FOR FORMATION.
Sugar	From carbon dioxide and water.	Chlorophyll, light, and heat.
Cellulose	From the protoplasm or is produced by it.	
Fat	From the breaking down of protoplasm, or secreted by it.	Can be formed in light or darkness.
Protein	By the protoplasm.	

PROTOPLASM.—The substance named by Mohl, protoplasm, is one of the most wonderful things in the Universe, for the whole of what we call life depends upon its existence, and up to the present, life has never been found apart from it. One of the familiar objects which may be seen on the bark in a tannery during summer, or on the staging of a greenhouse where the spent bark has been used, are masses of what looks like yellow jelly. This is known as “Flowers of Tan.” The masses of jelly consist of protoplasm, and if they are carefully observed from time to time, they will be seen to move slowly along the tan. No definite answer can be given as to the composition of living protoplasm, for it is impossible to make a complete analysis without destroying what we call life. It gives the same reaction as proteins, but it must differ from them, for it possesses living properties which they do not possess. We will now examine in a practical manner some of the properties of protoplasm.

102.—PRACTICAL WORK TO ASCERTAIN THE PROPERTIES OF PROTOPLASM.—(1) Obtain from a naturalist

a plant of *Vallisneria*, or some *Elodea* (American Water Weed), and mount a young leaf in water. Cover, and examine. Numerous small cavities will be seen, and if the temperature is suitable, the contents of these will be seen in a state of motion. Each cavity is known as a cell, and the substance which is moving within it consists of protoplasm in which different materials are embedded. Now carefully notice the movements of the protoplasm; the chlorophyll granules move with it, and seem as if they were running a race, for sometimes one grain may pass another, only to be passed in its turn by a more swiftly moving one. (2) Place the slide on a piece of ice for a few minutes. Examine again. The movement has ceased. (3) Set the slide on a glass containing warm water for a short time. On examination the protoplasm will be seen to have recovered the power of motion. (4) Pass the slide through a gas flame or hold it over the surface until the water begins to boil. All power of motion will have been lost. (5) The power of motion depends upon temperature. If the protoplasm is too cold or too hot it ceases to move, but recovers when a suitable temperature is obtained. Boiling destroys or kills the protoplasm. (6) Examine some flower of tan, and notice that it increases in size or grows.

PROPERTIES OF PROTOPLASM.—From the experiments just performed it seems clear that protoplasm possesses certain properties. These are :—

- (1) The power of movement.
- (2) The power of growth.
- (3) The power of reproduction (not shown in Experiment 102).

PROTOPLASM ENCLOSED IN CELLS.—In most plants the protoplasm is enclosed within cavities which receive the name of cells (Fig. 40). The word cell means a space

surrounded by walls. Plants are built up of cells, and in very young plants their walls consist of cellulose. Cells vary greatly in size, some are so small that they can only just be seen under the highest powers of the microscope, while others are visible to the naked eye. Both living and dead cells may be found in plants, the former contains

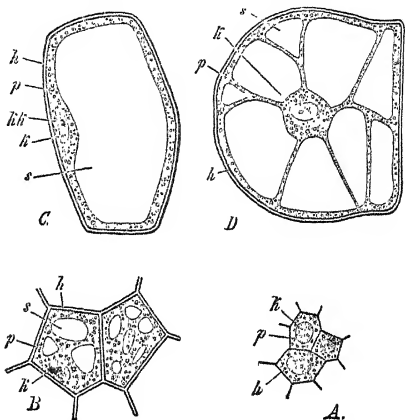


FIG. 40.—The structure of cells. *A*, young cells; *B*, older cells from same plant. *h*, cell wall; *p*, protoplasm; *k*, nucleus; *kk*, nucleolus; *s*, vacuoles. *C*, a still older cell with one large central vacuole. *D*, shows several vacuoles, and the central mass of protoplasm is connected to that which lines the cell wall by strands.

living protoplasm, but the latter are either empty or their contents are non-living.

TISSUES.—Cells may be grouped to form vessels, as in the vascular bundles. The union of cells give rise to what have been termed tissues, because they have been compared to a woven fabric. There are three classes into which tissues have been divided, they are:—

- (1) Covering or epidermal tissue.
- (2) Supporting, conducting, or vascular tissue.
- (3) Packing or ground tissue, which fills in the spaces between the above, and may have stored in them reserve and waste substances.

RESERVE MATERIALS IN PLANTS.—Most of the products which we have examined are stored up by plants for future use, and they have been termed reserve materials.

Starch.—One of the common reserve materials is starch, and it is stored up in seeds, leaves, stems, and roots (p. 82). It can be changed into sugar by a ferment.

Cellulose.—The reserve material which is stored up in the date seed is cellulose. When the seed germinates, the cellulose is changed by a ferment into sugar.

Proteins.—In all seeds or embryos a certain amount of proteins must be stored up to give to the young plant a start in life.

CONCLUSIONS.—From both the practical work and theoretical considerations the following conclusions can be arrived at:—

- (1) The food which plants absorb from the soil and air consists of raw materials.
- (2) The living activity of the protoplasm produces from the food numerous compounds.
- (3) The whole of the constructive work done by plants depends upon the protoplasm.
- (4) The protoplasm is the most wonderful substance in the Universe, and what we call life is always associated with it.
- (5) The protoplasm is in all cases found in cells, and in plants these are surrounded by walls.
- (6) The cells are arranged to form tissues, and these perform the work of supporting, conducting, protecting, and storing up materials.

CHAPTER XIV

PLANTS REQUIRE OXYGEN

RESPIRATION.—All plants, and all the living parts of plants, must be supplied with free oxygen so that they can produce energy. The taking in of oxygen, and the giving out of carbon dioxide is known as *respiration*. Nearly all plants must have the oxygen in a free state, not combined, as in a compound; the exceptions being a few bacteria, and the Yeast plant, which grows better without free oxygen than with it. Plants must possess energy, and like animals they can obtain it by the breaking down of substances which exist within themselves. Energy is the capability of doing work, and energy is just as necessary for the life of a plant as for the life of an animal. The only difference between plants and animals in this respect consists in the former requiring much less energy than the latter.

COMPOSITION OF ATMOSPHERE.—The atmosphere is made up of several gases which do not unite to form a compound, but exist in the form of a mechanical mixture. The following table gives the average composition of air:—

Nitrogen	.	.	.	79.00	per cent.
Oxygen	.	.	.	20.96	„ „
Carbon dioxide	.	.	.	0.04	„ „

In addition to the above, there are small quantities of aqueous vapour, ammonia, and nitric acid.

THE CHANGES PRODUCED IN THE ATMOSPHERE BY GREEN PLANTS AND ANIMALS.—In a previous section of this work we noticed that plants absorb carbon dioxide

from the atmosphere, and return to it oxygen. They also use some of the oxygen for respiration, and give up in return carbon dioxide. Respiration in plants is very feeble, but the assimilation of carbon dioxide is carried on with great vigour. So that green plants purify the atmosphere. Animals, on the other hand, respire with great vigour, they are always pouring into the atmosphere carbon dioxide, and taking from it oxygen. Those plants which are destitute of chlorophyll act in a similar manner to animals. The balance of carbon dioxide and oxygen in the atmosphere is kept up by the interaction of green plants and animals.

103. - PRACTICAL WORK TO PROVE THAT PLANTS ABSORB OXYGEN.—(1) Obtain some methylene blue, and mix a little with some water so as to make a pale blue solution. Prepare three small flasks, and number them. Fill No. 1 with the solution, and fix a cork in position. This is the control experiment for colour, and all dispute as to colour must be referred to this flask. Place in No. 2, a few germinating peas, and fill with the solution. In No. 3, place a few pieces of Watercress, and fill as before. Set the flasks in the dark for from two to three days. At the end of the above period, examine. The solutions in both 2 and 3 have changed colour. Why? Because both the peas and watercress have absorbed oxygen from the methylene blue, hence the change of colour. (2) Place in a piece of damp blotting-paper, a few germinating peas or beans, and insert into a glass jar. Close the jar with a tight-fitting cork, and set in the dark. At the end of twenty-four hours, see if a glowing strip of wood will burn in the bottle. If the experiment has been carefully done, the wood will not burn. The oxygen has been absorbed by the peas, and they have given out carbon dioxide.

104.—PRACTICAL WORK TO SHOW THAT CARBON DIOXIDE IS GIVEN OFF WHEN PLANTS RESPIRE.—(1) Plug up the hole in a funnel with a wad of loose cotton wool, and place in it some germinating barley seeds. Set the funnel in a glass jar, and cover the apparatus with a piece of dark woollen cloth or felt. At the end of twenty-four hours lift out the funnel, and pour some lime-water into the jar. Shake, it will turn milky. Carbon dioxide has been produced. (2) In a similar manner perform the experiment, but use flowers of the Marguerite or Dandelion. The result will be the same.

105.—PRACTICAL WORK TO SHOW THAT HEAT IS PRODUCED BY RESPIRATION.—(1) Obtain half a pound of barley seeds, and soak them in water for twenty-four hours. Remove from the water, and allow them to drain for some time. Now line the interior of a glass (a jam jar will do) with damp blotting-paper, and place the barley seeds inside it. This will keep the seeds damp. Insert a cork in the neck of the jar through the centre of which a hole has been made. Fix in the hole a thermometer, and keep in a warm room. Readings of the thermometer should be taken every ten hours for several days, and these should be compared with the readings of another instrument placed near the apparatus. This experiment shows that heat is produced when seeds germinate. Why? Because they respire, and the oxidation which goes on inside the seeds produce heat. (2) Perform a similar experiment but keep the apparatus in a cold place. How do the results obtained differ from the tabulated ones in No. 1? Has the temperature of the room any influence on the production of heat? (3) Prepare a bottle or jar like the one used above, and inside of the damp blotting-paper place a quantity of the flowers of the Marguerite. Insert the cork and thermometer. Do the flowers of the Marguerite

respire, and produce heat? (4) Buy two ounces of yeast, and mix it with some warm water and sugar. Place in a similar jar to the ones used above, only blotting-paper will not be required. Keep in a warm place. Insert the cork, etc. Take the temperature at once, and each thirty minutes. What is the result?

THE ACTION OF EXTERNAL TEMPERATURE ON RESPIRATION.—The results obtained by numerous experiments have proved that the temperature of the atmosphere has a marked influence on the respiratory activity of plants. Respiration nearly ceases at the freezing-point, but as the temperature rises, the absorption of oxygen increases until, at a point which varies in different plants, the maximum is reached. If the external temperature rises above the maximum, the respiratory activity declines. We can say, that all plants possess a minimum temperature below which the power of absorbing oxygen ceases, and in a similar manner, respiration ceases if the temperature rises above the maximum.

THE INFLUENCE OF LIGHT ON RESPIRATION.—Light does not seem to influence the activity of respiration, for plants respire in light as well as during darkness. In fact, we can say that respiration commences with the germination of the seed, and continues throughout the life of the plant.

WHY PLANTS RESPIRE.—The experiments which we have performed prove that heat is produced during respiration. When oxygen is absorbed, and it unites with substances within the plant, oxidation takes place. Oxidation is always accompanied by the liberation of heat, but heat is a form of energy. The energy produced by respiration enables the processes which are so important for the well-being of the plant to be carried out. It seems probable that the energy is necessary for :—

(1) *Assimilation.* A green plant when exposed to light, produces enough material in one hour to enable it to respire for thirty hours.

(2) *The growth of the plant.* If respiration ceases, the growth of the plant is arrested, and will not commence until oxygen is absorbed.

(3) *The movements which plants exhibit.* The movements of the sensitive plant are arrested if placed in an atmosphere which contains no free oxygen.

CHAPTER XV

TRANSPIRATION

PLANTS GIVE OUT WATER.—If green plants are exposed to light they give out the maximum amount of water as aqueous vapour, but in the dark only a very small quantity will be lost. The greater the quantity of vegetation in a district, the larger the quantity of aqueous vapour will be present in the atmosphere. The atmosphere in a forest is close and oppressive because the trees give out an immense quantity of aqueous vapour. Places which possess only a scanty vegetation generally have a dry atmosphere, and the rainfall will be very little. We will now proceed to ascertain from what part of the plant most of the aqueous vapour is lost.

106.—PRACTICAL WORK TO SHOW THAT A GREEN PLANT LOSES WEIGHT WHEN EXPOSED TO THE ACTION OF LIGHT AND HEAT.—(1) Obtain, in a plant-pot, a strongly growing Geranium plant and water well. Now cover the whole of the pot and soil with tinfoil so as to prevent them from losing water by evaporation. (2) Weigh the plant, and set it on a window sill where it is exposed to bright light for four hours. If a pair of scales cannot be obtained, this experiment can still be performed. Make a hole in the centre of a window rod, and pass a piece of string through it. Now suspend the rod by the string. Sling the plant-pot at one end of the rod, and balance with a bag containing sand. Let the apparatus be exposed to light for a few hours or stand in a warm well-lighted room. (3) At the end of four hours the plant should be weighed again. The decrease in

weight will give the amount of moisture lost by the plant. *Perform in a similar manner the following experiments:* (4) Weigh the plant used above and keep it for four hours in a dark cold room. How much water has the plant lost? (5) After weighing the plant, keep it for the same length of time in a dark warm room. What is the loss of weight? If the above experiments are carried out with care, they prove that when plants are exposed to bright light they lose more aqueous vapour than under any other condition.

107.—PRACTICAL WORK TO ASCERTAIN WHICH PORTION OF THE PLANT LOSES THE MOST WATER WHEN EXPOSED TO THE ACTION OF LIGHT.—(1) Select a woody plant, and cut from it (i) a piece of stem which bears about four leaves, (ii) a piece of stem without leaves. (2) Take two large test-tubes with tight-fitting corks. Perforate the corks. Now fix in one the piece of stem, and in the other the leaf-bearing twig. If air should enter the stem it prevents the passage of water up the wood. Cut from the lower ends of the twigs about one inch, this must be done under water so as to prevent air from entering the stem. Nearly fill the test-tubes with water, and insert the freshly cut ends into the tubes. Fix them firmly in position and weigh. Place in a stand, and expose to light. The twig which bears leaves loses the most moisture. *Now using the same apparatus perform the following experiments:* (3) Weigh the tube in which the bare stem is fixed, and set in a stand. (4) Fix in the other test-tube two leaves, weigh, and place in the stand. At the end of four hours weigh again. The test-tube containing leaves has lost the most moisture. The experiments which have been performed distinctly show that the leaves are the great factors concerned in the loss of aqueous vapour from plants.

108.—PRACTICAL WORK TO PROVE THAT LEAVES GIVE OUT AQUEOUS VAPOUR.—Obtain some Cobalt papers, or better still, prepare them in the following manner. Make a solution of cobalt chloride by dissolving a little in water. Dip into the solution pieces of unglazed white paper, and allow them to dry near a fire. If the papers have been properly prepared they will be of a blue colour. Allow a single drop of water to fall on a small piece, it turns red. Cobalt paper can be used to prove that leaves give out moisture. Expose a piece of the prepared paper by gumming it to a green leaf which is still attached to a stem, in a short time it changes from blue to red. Select a fairly large leaf, and fasten pieces of the cobalt paper to both the upper and lower epidermis. The piece which turns red the quickest has been fixed to the side of the leaf which gives out the most water.

109.—PRACTICAL WORK TO ASCERTAIN WHICH SIDE OF A LEAF GIVES OUT THE MOST AQUEOUS VAPOUR.—Select four leaves from an India Rubber plant. Weigh one, and set it in a tumbler or bottle of water. This is the control experiment, and as the leaf is under normal condition it can be used to test the following experiments. Now smear with vaseline, (i) the upper side of another leaf, (ii) the under side of still another leaf, (iii) both sides of the remaining leaf. Weigh them and set in water. At the end of twenty-four hours weigh again. This will enable certain conclusions to be deduced as to which side of the leaf loses the most aqueous vapour.

110.—PRACTICAL WORK TO ASCERTAIN THE STRUCTURE OF A LEAF.—(1) Boil a few evergreen leaves in a five per cent. solution of caustic potash for fifteen minutes. Separate the parts in a basin of cold water, and examine with a lens or microscope. (2) Examine a

leaf of the Laurel in a similar manner. Prepare a set of notes describing the structure of the above leaves.

111.—PRACTICAL WORK TO SHOW THE STRUCTURE OF STOMATA.—The student in performing Experiments 75 and 110, will have obtained a general idea of the structure of a leaf, and he must now proceed to examine the appearance of stomata. (1) Bend over the first finger of the left hand a leaf so that the under side is upwards. Now raise, with a sharp knife, the outer skin or epidermis, and gently pull off a small piece. Place on a glass slide, and cover with water. Examine with a hand lens or microscope. A series of small openings will be seen, these receive the name of stomata, and from these aqueous vapour escapes. (2) The epidermis from the upper side should be examined in a similar manner. (3) The best leaves for the above experiment are those of the parallel-veined type, as the Lily, Hyacinth, Daffodil, and Lily of the Valley.

112.—PRACTICAL WORK TO SHOW THE DISTRIBUTION OF STOMATA ON LEAVES.—Select branches from the Oak, Beech, Lime, and Elm. Plunge them in the order named into a dish of cold water, and gently shake. The parts which remain dry, contain the stomata, and those where the film of water spreads, have no openings. This shows that they must possess contrivances to prevent water from entering the stomata, and if a leaf is placed in water or the rain wets the leaf, it does not wet the parts so protected.

113.—PRACTICAL WORK TO SHOW THAT GASES CAN ESCAPE FROM THE STOMATA.—(1) Fill a dish with boiling water, and plunge into it a fresh laurel leaf. Bubbles of air escape from the under side only. (2) Cut a fresh leaf from a garden primula, and place the blade in a tumbler of cold water, blow gently down the stalk of the leaf. Bubbles of air escape from the stomata. These

experiments not only show that air can escape from the stomata, but how they are distributed on the leaf (p. 71).

THE MINUTE STRUCTURE OF A FOLIAGE LEAF.—A foliage leaf is covered with both an upper and lower epidermis, and these enclose a middle portion which receive the name of mesophyll. As seen under the microscope, the mesophyll consists of a layer of elongated cells which touch the upper epidermis, and are known as the palisade cells. Most of the cells contain small green bodies, the chlorophyll corpuscles (p. 75). The lower epidermis is in contact with another layer of cells, which is known as the spongy portion of the leaf. Numerous cavities exist between the cells, and they open on the surface by means of the stomata. The spongy portion also contains chlorophyll, but because of the numerous air cavities the amount of green colouring is much less, and it gives rise to the usual pale green colour of the under side of a leaf. The mesophyll is supported by the veins which we considered on page 68. Numerous hairs may be scattered over the epidermis. The epidermal cells of the leaves of most flowering plants do not contain chlorophyll, except around the stomata, and only a single layer of cells enter into its structure. The following illustrates the structure of most foliage leaves.

(1) An upper epidermis which consists of a single layer of cells: this is generally without chlorophyll, but stomata may be present.

(2) A mesophyll which consists of an upper layer of palisade, and a lower layer of spongy cells. This is supported by the veins of the leaf (p. 68).

(3) A lower epidermis of a single layer of cells, and in this numerous stomata are present.

STRUCTURE OF STOMATA.—The *stoma* is an opening between two cells which receive the name of *guard cells*,

and it opens into a cavity known as the *air-chamber* (Fig. 32). If the student has been able to see the preparation of the epidermis of a leaf with the high power, of the microscope (Experiment 74), the openings between the guard cells will represent stomata. The stomata are closed during the time the leaf is away from the light, but they open when it is exposed to the action of light. This explains why the leaves give out so much more moisture when exposed to light than when in the dark (Exp. 106).

TRANSPIRATION.—We have already noticed that plants lose weight when exposed to light, and that this is due to the escape of aqueous vapour from the stomata. The giving out of aqueous vapour by a plant is known as *transpiration*. All plants transpire, and this enables them to lose much of the water which is taken up by the root-hairs (p. 63).

HELPS TO TRANSPIRATION.—The leaves of plants which grow in damp places, such as marshes, have special contrivances to enable the excess of water absorbed by the roots to escape. The spongy portion of the leaf attains a great development, and the air cavities are very large and numerous. Aqueous vapour escapes from these cells into the cavities and out of the stomata. In some plants the spongy layer is developed to such an extent that the colour of the places where the largest number of cavities exist differ from the general surface, and the leaves appear to be spotted. If plants grow in the shade, or in swamps, they often produce very large leaves, *e.g.* Butter-bur and Cuckoo-pint. The large leaves carry more stomata, and this enables the plant to give out more aqueous vapour. In fact, the same kind of plant varies according to the position in which it grows; the largest leaves always being produced when a plant grows in the shade or in water, and the smallest ones when growing in a dry place.

Floating leaves, like those of the Water-Lily, have the stomata developed on the upper side only, and this allows the aqueous vapour to escape into the air.

HOW PLANTS PREVENT UNDUE TRANSPIRATION.—

There are no end of contrivances by which certain plants prevent undue transpiration. The heaths which grow on moors and commons where the soil easily dries up, have their leaves rolled or bent so as to expose the least surface to the air. Numerous other examples can be seen where plants grow in sand-dunes, and in hilly districts. If grass plants grow in sand the leaves are bent or rolled, and this tends to prevent excessive loss of water. The hairs which grow in such rich profusion on some plants protect them from drying too quickly. Plants with succulent leaves, like the House-leek, contain a large quantity of water, and so they prevent the rapid drying which is so dangerous to all living beings.

CONCLUSIONS.—Transpiration is necessary if a plant is to grow and reach its full development. It is principally by the giving out of aqueous vapour that plants can lose the water which is in excess of their requirements. On the other hand, if the transpiration is more rapid than the root can take in water, the plant flags. To prevent a too rapid transpiration plants have numerous contrivances: these are:—

- (1) The leaves being rolled or bent.
- (2) The leaves being covered with hairs.
- (3) The leaves being thick and fleshy.

When plants grow where it is damp, they generally produce large leaves so that a larger surface is exposed to the air. This promotes transpiration.

CHAPTER XVI

THE COLOUR OF PLANTS

COLOUR.—It seems probable that man has not always possessed the power of distinguishing beauty in colour, and that colour perception has been developed comparatively late in the history of mankind. The discovery of the composition of white light, by Newton, gave the necessary impulse towards a study of colour. By means of the spectroscope it can be demonstrated that white light is made up of seven primary colours. These are—

Red.	Green.
Orange.	Indigo.
Yellow.	Blue.
Violet.	

If white light falls on a sheet of white paper, it remains white because all the rays of light are reflected. On the other hand, if it falls on a red ribbon, it remains red because all the rays are absorbed except the red, which are reflected. This is also true of all the other colours; they absorb all the rays except those like themselves, and these they reflect. The following table illustrates this in the case of flowers.

FLOWERS.	REFLECT—	ABSORBS—
A red Rose . . .	The red rays . .	All the other rays in white light.
A yellow Marguerite	The yellow rays . .	
A blue Cornflower .	The blue rays . .	
A Violet	The violet rays . .	
A white Convolvulus	All the rays . . .	Does not absorb any of the rays in white lights.

PIGMENT IN PLANTS.—It is common knowledge to all, that plants vary in colour, and that a red apple is due to pigment in the skin. The colour in plants depend upon pigments. Chlorophyll is the most common one, and we have dealt with the use of this pigment in Chapter X. The pigments which give rise to blue, yellow, and red receive the name of anthocyanin. If the organ which contains the pigment is soaked in water, a coloured solution is obtained. Buttercups can often be seen that have lost their yellow colour, because it has been removed by the rain. This shows that the pigment is soluble in water. It seems probable that the colour of the pigment depends upon the amount of alkali or acid in the sap which percolates through the organ. If a red solution be obtained by soaking a piece of red skin from the apple or the fruits of the Mountain Ash, and a few drops of caustic soda solution are dropped into it, the solution changes its colour. In a few cases the colours of flowers, roots, etc., may be due to coloured particles in the protoplasm, *e.g.* Beet-root. The selection by the pigments of the different rays present in white light give rise to the variety of colour met with among plants.

COLOUR IN PLANTS.—The well-known Copper Beech contains chlorophyll, but it is masked by a copper-colour pigment. This is also true of the organisms which give rise to the phenomena of red snow, for high up in the Alpine regions large areas of the snow appear red. This is due to the immense numbers of a kind of Alga which is known as *Hæmatococcus*. It contains chlorophyll, and in addition red spots; millions of these plants growing together on the snow give rise to red snow. Numerous seaweeds or Algæ grow in the rock pools around the coasts of Britain; they may be red, brown and green. They all contain chlorophyll, but the red and brown contain red

and brown pigments. The colour of flowers are more or less associated with the attraction of visitors, but there may be other functions performed by the pigments. This brief description of the colours found in plants shows what a large field there is open for investigation, and one which will fully repay for the time spent in its study.

HEAT AND COLOUR.—The classical work done by the late Professor Tyndall on heat explained the relationship between colour and absorption of heat. For he distinctly proved that a dark object will absorb more heat from the sun than a light-coloured one. It is known to all well-informed gardeners and farmers that a dark-coloured soil will, other things being equal, be warmer when the sun is shining and produce an earlier and better crop than a less dark soil. The following experiments will make this clear.

114.—PRACTICAL WORK TO DETERMINE IF COLOUR HAS ANY INFLUENCE ON THE ABSORPTION OF HEAT.

—(1) Select a series of pieces of cloth of equal weight, such as black, brown, red, yellow, orange, blue, and violet. Each piece should be large enough to cover a thermometer. (2) Place on a window sill a number of thermometers, and cover them with the different pieces of cloth. Allow them to be exposed to direct sunlight for one hour. Now remove the pieces of cloth from the instruments, commencing with the black one, and book down the observed temperatures. The results distinctly show that colour is a great factor in the absorption of heat.

THE USES OF COLOUR IN PLANT LIFE.—If colour in plant life is as great a factor as in clothing, it can be reasoned that a red flower or fruit should absorb more heat than a similar white or yellow one. If this is the case, it will explain why numerous young leaves are coloured red, and why at a later period they become

green. The red colour may enable them to absorb more heat, and thus to grow quicker, but when growth has nearly ceased the chlorophyll enables them to assimilate better than if masked with another colour. There is still another use that may be suggested for the pigment in the Copper Beech or in red leaves, that it protects the chlorophyll from decomposition by the action of intense light. It is well known to botanists that light is necessary for the production of chlorophyll, but if very intense it may destroy it. The leaves of the Butter-bur often show a different coloration on the under side of the leaf to the upper. For the side towards the ground may be of a pale violet colour, and the late Professor Kerner suggested that this may change the rays of light which pass through the leaf into heat.

LIGHT AND GROWTH.—The influence of light on the growth of plants is one which has formed a fertile source of discussion among botanists. Many parts of plants grow remarkably well in the absence of light, and underground organs have to do without its action. But it is also certain that all the exposed parts of plants must have light for healthy growth to take place. If the seeds of mustard are germinated in the dark, and the seedlings grow without being exposed to light, they are three times as tall as others which have developed in the light. This is only true for green plants, for the fungi grow even better in the dark than in the light. Another great factor in the growth of plants is the length of time they are exposed to light. Plants develop much quicker in mountainous districts where they receive light for several hours longer each day than down in the valleys. The author has often noticed that some plants flower earlier in the Lake District and in the Alps than in low-lying districts.

LIGHT AND THE MOVEMENTS OF PLANTS.—We

considered the movements of leaves in Chapter IX, and noticed that they arranged themselves so as to obtain the maximum amount of light. When plants grow under the shade of trees, they are long and lanky; the stems being slender, and the leaves small. If light produces curvature, and plants are equally illuminated on all sides, as under the shade of trees, they will grow straight. Window plants always show the action of light in producing curvature. Some parts of plants are attracted by the light, while others bend away from it. The student should make observations of the action of light on the growth and movements of plants and their organs.

AUTUMN TINTS.—Nearly every one must have noticed the change of colour which plants show throughout the year. In the early spring the delicate green of the larches is one of the wonders of the Lake District; in summer they change to dark green, and this gives way in autumn to a variety of colours. This is equally true of the brackens on the moors, for the pale green of spring changes to the wonderful colours which can be seen in October and November. This is true of all plants except those where the leaves fall too early, as near towns, or in the case of evergreens. The following is a short summary of what is known as to the changes which produce autumn tints:—

(1) The food materials in the leaves are rendered soluble, and removed into the stem or some other part of the plant to be stored up for future use.

(2) The chlorophyll is either all removed from the leaves, or only some of it, and the remainder changed into Xanthophyll—a yellow pigment. This pigment produces the yellow tints so often seen during October.

(3) The chlorophyll may be removed slowly, and the leaves change colour so that greens, yellows, etc., produce a variegated appearance.

(4) The red colour may be due to the formation of a new pigment anthocyanin which colours the sap red. From this pigment all the various reds, orange, blues, etc., arise; the change from one to the other depending upon the absence of acid or its presence in the sap.

(5) The changes seem to depend upon the temperature. For during August or early September, when frosts are the rule, the change may commence, or at a still later period of the year.

CHAPTER XVII

THE FLOWERING PLANT

A TYPICAL FLOWERING PLANT.—To obtain a concrete idea of the structure and functions of flowering plants, it will save time if we select and study the structure of one typical plant. From the observed characters of a type plant, we can draw certain inferences of the characters of the group to which it belongs. It is true that plants differ very much in structure, and that a type form always suffers from the number of exceptions discovered; but, in spite of this, the method of studying types possesses many advantages. For instance, the number of different plants living to-day probably exceeds 100,000, and no ordinary man can afford the time necessary even to study representatives of most of the great groups. The number of persons are very numerous who wish for some knowledge of plant life, without entering too much into detail. The type method, which was introduced by the late Professor Huxley, enables one to gain a broad outlook of the plant world in general.

In selecting a type to represent flowering plants, it has been necessary to choose a common plant, and one which can be obtained nearly everywhere. The Garden Pea seems to be well adapted, for seeds can be obtained at most shops, and at a cheap rate. They can be germinated and grown in schools or houses, with the minimum amount of trouble. Most gardeners grow them, and for over six months in the year they are common in gardens. It is also possible to preserve portions of the plant in

methyated spirits. We will now commence the study of the Garden Pea, and if there is any difficulty in obtaining specimens, the Sweet Pea or Bean can be substituted.

115.—PRACTICAL WORK TO ASCERTAIN THE EXTERNAL STRUCTURE OF THE GARDEN PEA.—The student should make out on the Pea plant the following.

(1) *Roots*.—The primary root of the seedling has formed a tap-root, and it tapers downwards towards the apex (p. 59). From this numerous secondary roots grow, and these carry tertiary roots. Both the primary and secondary roots have a series of root-tubercles growing on them. In these numerous bacteria live, and they produce, from the nitrogen in the air, compounds which pass into the Pea plant (p. 103).

(2) *Stem*.—Note the stem is slender, and it climbs by means of tendrils. It is round, hollow, smooth, and pale green in colour. Numerous compound leaves spring from the stem.

(3) *Leaves*.—The leaves are cauline, and alternate (p. 66). Each leaf consists of from four to six leaflets, and the midrib and some of its branches have been converted into tendrils. These probably represent the number of leaflets which have been changed into climbing organs. At the base of each leaf, and sheathing the stem, a pair of large *stipules* will be found. The stipules are outgrowths of the base of the leaf, and they may be mistaken for foliage leaves. Both the stipules and the foliage leaves are green, and they both take part in carbon assimilation.

(4) *Flowers*.—The flower of the Sweet Pea is described on p. 7, and a comparison of this with the structure of the Garden Pea should be made.

(5) *Fruit*.—The fruit is a pod, and it contains several seeds. These are fixed on alternate sides of the middle line of pod. In some cases one or two peas have not

developed ; they have either not been fertilised, or all the nourishment was sent to the other seeds, with the result that they degenerate.

(6) *Seeds*.—For the structure of the seeds, see p. 28.

116.—PRACTICAL WORK TO ASCERTAIN THE INTERNAL STRUCTURE OF THE STEM.—(1) Select a piece of stem which carries two or three leaves, and with a sharp knife slit it lengthwise into two halves, so as to pass through the bases of the leaves. Note the vascular bundles ; they run up the stem and pass into the leaves. The nodes are solid, and to see the course of the bundles the soft material should be removed with care. Slit open the petiole of one of the leaves and trace the bundles into the leaflets. The silvery-looking leaf-trace bundles will be seen to pass into the leaflets and tendrils. (2) It is evident that there is a connection between the bundles in the stem and those in the leaflets.

117.—PRACTICAL WORK TO ASCERTAIN THE INTERNAL STRUCTURE OF ROOTS. — (1) Slit up the primary root, so that the section made shall pass through the bases of a few secondary roots. Try and trace the vascular bundles from the place where the root joins the stem, downwards towards the apex. Note how they approach closer and closer together, until they unite to form a central ring. If possible follow them into a secondary root. (2) The only deduction which can be drawn from the examination of the roots, are (i) the bundles in the secondary roots join on to those in the primary one, and these unite with those in the stem. The leaf-trace bundles are joined to those in the branches and main axis of the plant ; (ii) thus the whole of the vascular bundles of the plant are united to form a definite vascular system, and through this water passes from the roots to the leaves.

118.—PRACTICAL WORK TO ASCERTAIN THE STRUCTURE OF THE LEAF.—(1) Remove a small portion of the epidermis from the under surface of the leaf, and mount it in water. Note the appearance of the stomata and outline of the cells (Fig. 32). (2) In a similar manner examine a portion of the upper epidermis. How does it differ from the lower epidermis? (3) It is too difficult to prepare a transverse section of the leaf, but a general idea of the structure can be obtained from Fig. 32, and the description given on page 122.

REPRODUCTION.—The Pea plant is an annual, and the only way in which the life of that particular species can be carried on from year to year is by means of seeds. We have already noticed in a general way the processes which are necessary for the production of seeds, and it remains for us to study the process more in detail.

STRUCTURE OF PISTIL.—The pistil of the pea consists of a single leaf, which is folded and united by the margin. It contains two rows of ovules, and these are fixed to the carpel along the ventral surface, so that they alternate.

STRUCTURE OF OVULE.—The ovule of the pea is not so well adapted for examination as that of the "Black Bindweed" (*Polygonum Convolvulus*), for if sections are cut through the ovule, the structures shown in Fig. 8 can be made out. The *oosphere* is the egg-cell from which the embryo will be formed after fertilisation, and the two cells associated with it only guide the pollen tube when it enters the embryo sac. In the centre of the embryo sac a large nucleus is seen; this forms the endosperm after fertilisation (p. 30).

POLLINATION.—Nine of the stamens are united, and the tenth is free. Butterflies, moths, and bees visit the flowers in search of nectar. A bee settles on the wings (p. 18) of the corolla, and this pulls the stamens outwards

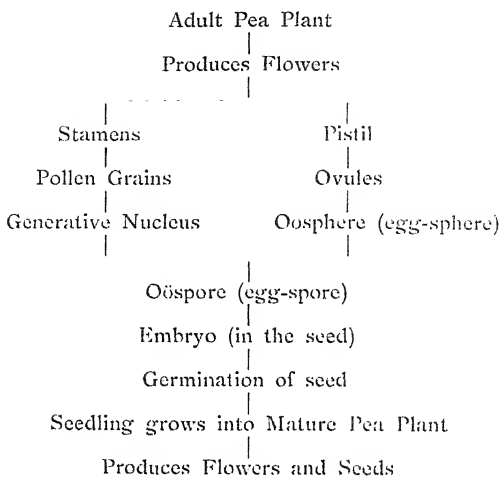
so that they dust the visitor with pollen. The bee passes on to another flower, where some of the pollen is deposited on the stigma. This process is known as cross-pollination (p. 22). In some parts of Europe the edible pea is self-pollinated.

FERTILISATION.—The pollen grains which have been placed on the stigma germinate, and pollen tubes are produced. These grow down the style and enter the ovary. They are attracted by sugar towards the micropyle of the ovule, and one enters it and passes in between the two cells near the oosphere, or ovum. The tip of the tube opens and liberates the generative nucleus; this unites with the oosphere, and fertilisation is completed.

RESULTS OF FERTILISATION.—After fertilisation the corolla and stamens fall off. The ovary swells up to form a pod, and the ovule changes into a seed. During the time that the above changes go on the parent plant has been busy collecting food materials and changing them into sugar, proteins, etc. These are deposited in the embryo (in some plants in the seed), and thus the parent provides for the early stages in the growth of the young seedling. In fact, the life of the embryo depends upon the parent, and the thousands of generations of peas have all been connected together, the life being handed down from parent to offspring. The health of plant life depends for its continuation upon sexual reproduction, and if from any cause all the seeds produced by a single species of annual plant could be destroyed, that particular form would become extinct.

LIFE HISTORY.—The life history of the Pea plant commences with the formation of the embryo, and ends with the death of the adult plant. This is shown on the following page:—

PLANT LIFE



CHAPTER XVIII

THE FERN PLANT

GENERAL VIEW OF BRACKEN FERN.—The fern plant which is selected as a type is known as the Bracken Fern. It grows in woods, on moors, and heaths, and is very widely distributed in the British Isles. When it is viewed in its native haunt, the only portions which can be seen above ground are the large branching, leaves or fronds. They may stand several feet high; each one consists of a central stalk from which numerous branches arise, and from these leaflets spring. If the soil is removed from the base of the leaves, there will come into view an underground stem—the rhizome. It is long, branches, and creeps along beneath the surface. Numerous rootlets spring from it, and these parcel out the soil. The bases of numerous old leaves will be seen, and by means of these the amount of growth can be measured.

119.—PRACTICAL WORK TO ASCERTAIN THE EXTERNAL STRUCTURE OF THE RHIZOME.—Select one rhizome, and carefully examine it. (1) Note the colour of the rhizome, and the bases of the old leaf stalks. (2) Find the apex, it is conical, and in the slight depression at the apex there is a growing-point. (3) Examine the base of one of the leaves of the current year. Buds may be seen to spring from it. (4) Examine the adventitious roots, as they are called, because they spring from the rhizome. They are scattered over the surface of the rhizome, and do not appear to grow in regular order. The rhizome is of a dark brown colour, due to a layer of brown material which covers the whole of the stem.

120.—PRACTICAL WORK TO ASCERTAIN THE INTERNAL STRUCTURE OF THE RHIZOME.—(1) Cut the rhizome transversely, and examine the cut surface. There will be seen—(i) an outer dark band of material which is known as the outer sclerenchyma. (ii) A more or less light-coloured ground mass, which consists of ground tissue. (iii) Scattered masses of dark sclerenchyma which help to strengthen the rhizome. (iv) Several oval or roundish-shaped vascular bundles of a yellowish colour. (v) Two thin places in the outer layer, these are known as the lateral lines. (2) Cut a longitudinal section of the rhizome, and note (i) the outer sclerenchyma. (ii) The white ground tissue. (iii) The scattered masses of dark sclerenchyma which run lengthwise through the stem. (iv) The yellowish vascular bundles which also run lengthwise. (3) Treat a section with iodine solution. This will show the distribution of starch.

121.—PRACTICAL WORK TO ASCERTAIN THE STRUCTURE OF A ROOT.—(1) Carefully examine a root which is still attached to the rhizome. This can be done by dissecting away the substance of the rhizome so as to expose the place where the root originates. The roots of ferns develop from the outer layers of the rhizome. (2) The root branches and grows by means of an apical cell.

122.—PRACTICAL WORK TO SHOW THE STRUCTURE OF A LEAF.—Obtain a leaf of the bracken fern, and make out the following parts: (1) The leaf is compound and green. (i) Cut across the stalk; the vascular bundles, etc., are arrangements on the same general plan as in the rhizome. (ii) The upper surface is of a deeper green than the lower. (2) Tear off a small portion of the lower epidermis, and mount in water (p. 71). Note the characters of the stomata, and that the cells of the epidermis contain chlorophyll. (3) Prepare

in a similar manner a portion of the upper epidermis. Its structure differs from the lower surface in having no stomata. (4) If a transverse section of the leaf can be obtained, and examined by the microscope, the structure will be seen to be essentially similar to that of the flowering plant. (5) Remove the end from a young frond or leaf, and note that its growth in length is arrested. This shows that the growth in length is due to a growing-point at the apex of the frond.

REPRODUCTION OF THE BRACKEN FERN.—If the edges of the leaves of the Bracken Fern are examined, during summer, some of them will be seen to slightly turn up, and beneath them long brown bodies will be seen. The edge of the leaf is known as the *indusium*, and the brown object which it covers is a *sorus*. Thus the indusium protects the sorus from injury. Each sorus is placed on a swollen portion of the leaf which is known as the *placenta*. The sorus contains a number of sporangia. A sporangium consists of a stalk on the top of which is a more or less elongated head, which contains numerous brown spores.

123.—PRACTICAL WORK TO ASCERTAIN THE STRUCTURE OF SPORANGIA AND SPORES.—(1) Remove from the edge of the Fern leaf a little of the brown material and mount in water. Cover and observe. Numerous sporangia will be seen, and round the wall of each a nearly complete ring of cells will be clearly seen. This is known as the annulus. The sporangium is united to the placenta by a stalk which is known as the pedicle. (2) Sketch and mark on it the pedicle, annulus, and spores. (3) Run beneath the cover-glass a little glycerine. Observe and note—(i) that as the glycerine reaches the sporangia, they break open and liberate the spores. (ii) They break open, in every case, at the place where the annulus is incomplete, and the portion of the head moves

about as if endowed with life, the spores being scattered.
(iii) The spores have a definite shape. Show this by a sketch.

SUMMARY OF STRUCTURE OF SORUS. The sorus is on the under side of the Fern leaf, and the edge of this protects it from injury. Each one contains a number of sporangia. A sporangium consists of a pedicle or stalk on which is fixed an elongated head. The annulus is a rim of cells which nearly encloses the head of the sporangium, and the weak place in this causes the head to break open when the pressure varies. The spores are produced inside the sporangia, and it not only protects them, but aids in their distribution.

THE ORIGIN OF THE SPORANGIUM. A single cell from the under side of the fern leaf grows outwards, and this is cut off by a wall. This divides into two cells, the bottom one by its development produces the pedicle, and the upper one divides again into a series of cells. The outer layer of these by division build up the annulus and wall of sporangium, and an inner layer forms the tapetum. From the central cell, the whole of the spores are produced. It divides into a number of mother-spore cells, and each of these form by division four spores.

THE SPORES.—If a mass of protoplasm divides into a number of spores, they are said to be *asexual*, in contradiction to where a spore is formed by the union of two masses of protoplasm, when they are sexual spores. The fern spores are *asexual*. Each spore is a cell, and it contains a nucleus (p. 111). The differences and resemblances between spores and seeds are shown below :—

- | | |
|--|----------------------------------|
| (1) The spore is unicellular. | (1) The seed is multicellular. |
| (2) The spore does not contain a young plant or embryo—the prothallus. | (2) The seed contains an embryo. |

- (3) The spore will produce a plant—the prothallus. (3) The seed will give rise to a plant, or the embryo will develop into a seedling.

124. PRACTICAL WORK TO ASCERTAIN THE METHOD OF DEVELOPMENT OF SPORES.—Place a few Fern leaves during August or September in a paper bag, and allow them to hang up for a few days in a warm room. Shake the bag, the spores fall out of the sporangia, and they will be found at the bottom of the bag when opened. Scatter these on a damp tile, brick, or some peat in a plant-pot. Keep moist, and watch development. The surface of the tile or peat at the end of several weeks will be covered with a green growth. This consists of young prothalli, which is the name given to the plants which the spores produce.

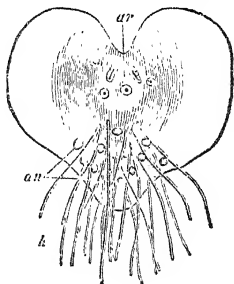


FIG. 41.—Diagram showing under side of prothallus of Fern, magnified about ten times. *ar*, archegonia; *an*, antheridia; *h*, root-hairs.

125.—PRACTICAL WORK TO DISCOVER THE STRUCTURE OF A PROTHALLUS.—

(1) Obtain from a gardener a few prothalli. These can be found growing on the walls, plant-pots, etc., in a fernery. Examine one. It is more or less heart-shaped and green, and about $\frac{1}{4}$ of an inch in diameter. A prothallus consists of a flat plate of cells: that this is the case will be seen if it is mounted in water, and examined by the aid of the microscope. Note the numerous hair-like bodies which grow from the under side. (2) Observe the under side of the prothallus with the microscope.

The central portion consists of several layers of cells; on this there will be seen (i) a number of rounded bodies among the hairs, and (ii) a few elongated bodies towards the indented part. The rounded bodies receive the name of antheridia, and the elongated ones are archegonia.

THE PROTHALLUS.—The prothallus is formed by the

germination of a spore, and on the lower surface reproductive bodies which are known as *antheridia* and *archegonia* are developed. (Figs. 42 and 43.)

THE ANTHERIDIUM.—An antheridium is the male organ of reproduction, and it grows among the hairs or rhizoids. Each one consists of a wall which is made up of three cells, and the central cell divides up to form mother *spermatozoid* cells. Changes take place in the contents of a mother spermatozoid cell, and a single motile body is formed, the *spermatozoid* or *antherozoid*. The antheridium, in the presence of water, bursts open, and the spermatozoid swims in it

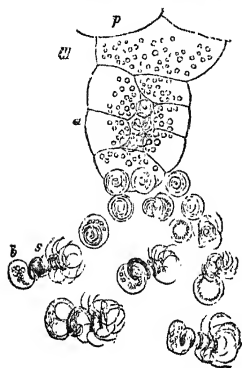


FIG. 42.—A single antheridium liberating spermatozooids. *p*, cells of prothallus; *a*, antheridium; *s*, spermatozooids; *b*, a small bladder which contains starch. (Very highly magnified.)

by the action of cilia. A spermatozoid consists of a flattened band of protoplasm, which is bent in the form of a corkscrew, and numerous cilia enable it to move in water. The antheridium is said to be the male organ of reproduction, because it produces a motile cell, the spermatozoid, which is the active agent in reproduction.

THE ARCHEGONIUM.—The archegonium is the female organ of reproduction, and its lower end is deeply sunk in

the body of the prothallus. It is elongated, and its walls are made up of three rows of cells; these enclose a central row of cells. The lower of the enclosed cells is known as the *oosphere*, or *ovum*; it is in reality an egg-cell, hence the name. The upper portion of the archegonium contains neck-canal cells, and below these a ventral canal cell exists. The oosphere is a passive agent in reproduction; when the archegonia is ripe, the cells in its neck absorb water, and are converted into mucilage. The pressure of the mucilage bursts open the top of the archegonium, and some of it protrudes.

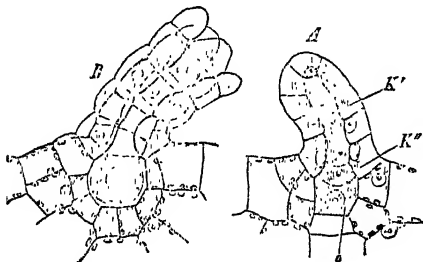


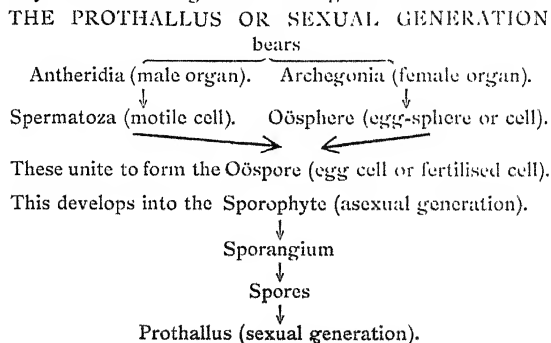
FIG. 43. *A*, young archegonium of Fern—closed. *B*, an open archegonium; *K'*, neck-canal cells; *K''*, ventral canal cells; *o*, young oosphere. (Highly magnified.)

FERTILISATION.—The union of the spermatozoid with the oosphere is known as fertilisation, and this always takes place under water. When the antheridium breaks open, the spermatozooids swim in water, and they are attracted to the archegonium by *malic acid*, which acts in a similar manner to the sugar in the ovule of a flowering plant (p. 20). That malic acid is the attracting medium can be proved by placing a very small glass tube which contains a little malic acid in the water in which spermatozooids swim, for they enter the tube. The spermatozooids

make their way through the mucilage, and one of them unites with the oösphere.

RESULTS OF FERTILISATION.—The oösphere by fertilisation is changed into an oöspore or fertilised egg-cell, and this surrounds itself with a cell-wall. It then divides into a number of cells, some of which form the first root, the stem, and growing-point of leaf. There is also produced from the embryo a group of cells which unite the young plant to the prothallus. This is known as a *foot*, and it absorbs food from the parent until it can look after itself. The prothallus dies away, and the young Fern grows into an adult plant.

ALTERNATION OF GENERATION.—The reproduction of the Bracken Fern, like other ferns, shows an alternation of generation. By the “alternation of generation” we mean that there are two generations in the life history of the Fern. The Fern plant is known as the *sporophyte*, or spore-producing plant, and its spores when they germinate give rise to the prothallus, the oöphyte or egg-bearing plant. The sporophyte is the asexual generation and the oöphyte the sexual. They alternate, as we have seen, in the life history. The following tabular arrangement illustrates this.



CHAPTER XIX

CULTIVATED PLANTS AND COMMON TREES

THE STRUGGLE FOR EXISTENCE AND NATURAL SELECTION.—That there is a struggle for existence among wild plants is well known to all persons who have considered how they live; for the area of the globe on which land plants can live is only of limited extent, and from this all such plants have to obtain their food. In any given quantity of soil there is only a comparatively small amount of plant food, and the plants which live in this soil have to divide it between them. If there are more plants living with their roots fixed in the soil than there is food for, only those which have some advantage over their fellows

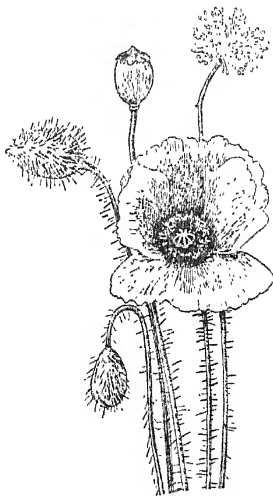


FIG. 44.—Flower, bud, fruit, and stamens of Poppy.

can hope to survive in the struggle which must take place for food. The ones which are able to produce seeds, and endow their offsprings with the greatest vitality will be the most likely race of plants to survive in the struggle which goes on for existence. In addition to the limited amount of food in the soil, plants have a tendency to produce more offsprings than there is room for, and this makes the struggle for food, etc., very keen. There arises from this process what the late Charles Darwin called "Natural Selection." This means that nature works in such a way that only the best-adapted individuals come to the top, and that the others are squeezed out of existence. It does seem very hard that such a thing should go on in every plot of land, but, nevertheless, it is perfectly true that nature has no sentiment, and only those plants which can adapt themselves to the changed conditions of life can hope to survive. If the student will only count the number of plants living, say, in a square foot of soil, he will be able to understand how keen is the struggle for existence, and that there must arise from this what is called Natural Selection.

VARIATION.—There is a constant tendency for the offspring of any pair of individual plants to vary. This is well shown if a number of fruits from a typical plant are carefully saved, and the seeds which they contain are germinated: some of the adult plants will most likely vary from one another, and from their parents. The gardener often calls the plants which vary from the original type "sports," and in many cases these may form valuable breeds of cultivated plants. No two plants are exactly alike in external appearance and internal structure, and this is what we mean when we speak of variation. The reason why plants vary is not fully understood at present, but it may be largely due to *adaptation*, to *environment* or

surroundings. The variations of both cultivated and wild plants may be due to stimulation of the protoplasm by new factors which arise from new conditions. Thus changes in food supply, amount of light or heat received must be factors that alter both the vegetative and reproductive organs of plants. From experiments performed it seems that new races of plants may appear at once as mutants, or sports, or they may be produced by the accumulation of small variations. The former view is held by De Vries, and the latter by the late Charles Darwin. It seems probable that both of the above theories may be correct, and that new species may arise as mutants, as in the case of the experiments carried out by De Vries, or they may be due to the accumulation of small variations which are favourable to the plant in the struggle for existence.

HEREDITY.—Both plants and animals inherit from their parents certain characters, and this is what is meant when we speak of *heredity*. If any advantage which a plant has over its competitors can be handed down to its offsprings, there is no doubt that this will give them a far better chance in the competition for food, etc. All biologists are agreed that heredity is a fact, and the discussion only takes place on how it is brought about.

CULTIVATED PLANTS.—The plants which grow in a garden live under very different conditions to wild plants, for there is no struggle for existence, as the gardener carefully removes all weeds, and prevents overcrowding. Weeds are produced from the seeds lying dormant in the soil, or from the seeds which find their way on to the garden by the action of the wind or animals. Thus a turnip growing among cabbages would be a weed, but if growing among plants of its own kind would not be a weed. The gardener also selects those plants the

characters of which become nearest to his ideal of what the plant should be for seed production, and in this way he can obtain better-developed and more productive varieties. In most cases, the soil is well worked, drained, and plant food is mixed with it as manure. Thus cultivated plants are spared all the difficulties which their wild relations have to contend with, and with the exception of parasites which may prey upon them, their life is very uneventful.

REVERSION.—On the other hand, the gardener must always be constantly on the watch for “reversion,” for cultivated plants have a tendency to revert to the ancestral type. This is owing to the selection of characters which may not be for the benefit of the plant, but only adds to its value as a vegetable or for ornamental purposes. It is also true that garden plants are more likely to fall victims to parasites than their wild relations. They are also not so well adapted to withstand keen competition as wild plants, for in a neglected garden the wild forms simply drive out the cultivated ones, or the latter are so modified in the struggle that they revert to the wild form. The student should examine any disused garden, and note what plants have become dominant.

THE ORIGIN OF CULTIVATED OR GARDEN PLANTS. —

All the garden plants have been produced by selection from wild forms, and De Candolle¹ has traced the origin of most of the plants which man cultivates for food. It is true that the origin of the cereal grains has been lost in the antiquity of the race, but they cannot be an exception to the rule, that from wild plants all the cultivated ones have arisen by careful selection and attention. Man has not only selected certain wild plants, and from these by careful selection have come all the numerous forms of cultivated

¹ *Origin of Cultivated Plants.*

plants ; but new varieties of seeds and fruits are constantly being produced. The various forms of wheat which farmers now cultivate give a far greater produce than those used a century ago. This is also true of potatoes, turnips, beet, cabbage, rhubarb, etc.

HOW CULTIVATED PLANTS DIFFER FROM WILD PLANTS.—Garden plants have a tendency to produce double flowers, and they vary in colour from their wild prototypes. Wild wallflowers are yellow, and have 6 stamens (2 short and 4 long), but the garden ones are reddish brown, and the short stamens tend to become long. The cultivated roses have been produced from the wild rose, and the numerous petals of the former are the result of the stamens and carpels being converted into petals. Even wild roses can often be found which have above the normal number of petals. This is also true of most garden plants, for in the cultivated daisy the tubular florets of the disc have become ligulate like those of the ray. The student should take every opportunity of examining garden plants and compare them with the wild forms. Garden plants not only differ in colour, etc., of the flowers, but the foliage leaves and stems have a tendency to grow larger. This is due to the more abundant supply of food, etc.

COMMON TREES.—In Chapter VI, we have considered the structure of some common buds, and the characters of these will enable the Horse Chestnut, Sycamore, and Lilac to be recognised during winter and early spring. If the student learns to recognise the above trees in winter, and will carefully examine them during summer, there will be no difficulty in distinguishing such trees no matter where they may grow. The Ash can always be recognised by its light-coloured bark and black buds, and in many cases even during winter and early spring clumps of fruits may

still adhere to the branches. The foliage leaves are compound, and the flowers are produced while the tree is destitute of leaves. The Oak can always be distinguished from other trees by the shape of its foliage leaves and the way in which it branches. The student should make a practice of noting the characters of the trees which grow in his district, for it is only by work in the field that a practical acquaintance can be obtained of common British trees.

CHAPTER XX

PLANT SOCIETIES

WILD PLANTS.—If the plants which grow on moors, heaths, mountains, hedgerows, sand-dunes, waste lands, and neglected gardens are examined, they will be found to live together in communities or societies. In all cases where man does not interfere with the growth of plants, such societies are common, and Professor Hæckel has proposed that the study of plants and animals in their native haunts should be known as *Ecology*. The student can find numerous examples of such societies near his own home, and there is no more fascinating study than that of why very different plants live together in particular localities. In one place there will be found growing together the Stinging Nettle and the White Deadnettle. It seems probable that the Stinging Nettle protects its companion from being eaten by animals, and they may also afford shelter from the cold winds of spring or the intense heat of summer. On heaths and moors the Gorse and Ling live side by side, and this may be due to the dry conditions of the soil being favourable to their full development. On mountain slopes, a society of Brackens may be seen, the fronds of which stand nearly six feet high, and very little else can live under the shade of the closely growing aerial parts of these vigorous plants. In the month of April and May, some ponds are white with the flowers of the Water Crowfoot. If a plant is removed from the water the leaves which are entirely submerged will be found to be dissected or very much divided, while

the floating ones are more or less reniform. This seems to show that different conditions or environments produce changes in the foliage of plants. If the pond dries up, the submerged leaves die, but the floating ones enable the plant to live for a considerable length of time.

THE KINDS OF WILD PLANTS.—In addition to the classification of plants given in Floras, they can also be arranged into four classes according to the conditions under which societies are formed. These are:—

KINDS OF SOCIETY.	CONDITIONS OF GROWTH.	EXAMPLES.
Xerophytes . . .	Moors, heaths, sand-dunes, and all dry places.	Gorse, Broom, Bracken, Lichens, Ling, Crowberry, Bilberry, Pines, etc.
Mesophytes . . .	Woods, pastures, meadows, gardens, and arable land.	Oak, Elm, Beech, Sycamore, Horse Chestnut, Ash, many Grasses, Clover, Poppies, Corn-Cockle, Arum, etc.
Hygrophytes . . .	Marshes, bogs, sides of ponds, lakes, ditches, and damp ground.	Pilewort, Marsh Marigold, Iris, Forget me not, Mint, Club Moss, Meadowsweet, Mare's-tail, Loosestrife, many Willow Herbs, etc.
Hydrophytes . . .	Ponds, lakes, rivers, ditches, tarns, and stagnant water.	Pilewort, Burweed, Duckweed, Pondweed, Water Crowfoot, Water Fennel, Water Millfoil, Water Starwort, etc.

XEROPHYTIC SOCIETIES.—Plants which can withstand periods of drought are known as *xerophytes*, and they form societies on moors, heaths, sand-dunes, dry banks, and slopes of hills and mountains. Xerophytes are especially adapted to prevent loss of water by transpiration, and this is prevented in the Gorse by the development of branches and leaves into spines. The

student should notice the structure of xerophytes, and the following is an outline of what to look for :—

(1) Is the plant covered with spines, and if so, are they produced from branches or leaves, or both? *E. g.* Gorse.

(2) Is the plant modified so that the leaves are small, and is the stem green and winged? *E. g.* Broom.

(3) Are the stem and leaves fleshy, and do they contain cavities? *E. g.* Sedum.

(4) Are the leaves rolled so that the under surface which bears the stomata is enclosed in a cavity? *E. g.* Crowberry.

(5) Do the leaves fit into each other, so that during drought or cold weather the minimum amount of surface is exposed to the atmosphere? *E. g.* Ling.

(6) Are the leaves needle-shaped? *E. g.* Firs.

(7) Are the leaves evergreen and thick? *E. g.* Holly.

(8) Are the leaves very much divided? *E. g.* Sweet Cicely.

The conditions under which the above plants grow have modified them in such a way that the minimum amount of water will enable them to exist, and it is very probable that the habit of the Gorse of flowering twice a year—in March and September—depends upon the rainfall or available water. Different plants have adopted different means of preventing loss of water, and if the seeds of xerophytes germinate in damp soil, the stems and leaves of the seedlings are much modified, and the spines are much reduced or entirely disappear, leafy shoots taking their place. This is well illustrated by examining the Rest-harrow, for if it is growing in dry soil, the spines are very numerous, but in damp soil well-developed branches and leaves are produced.

MESOPHYTIC SOCIETIES.—The plants which come between the xerophytes and hygrophytes are known as

mesophytes. There is no sharp line between mesophytes and xerophytes on the one hand, or between the former and hygrophytes. A plant which is a mesophyte under certain conditions may become a xerophyte or hygrophyte when the environment is favourable. Mesophytic plants have thin leaves, which bear numerous stomata, and they can give out large quantities of aqueous vapour. The common grasses of meadows and pastures, woody trees, such as Oak and Beech, are mesophytes. The student should proceed to examine the structure of such plants.

HYGROPHYTIC SOCIETIES.—The plants which love moisture are known as *hygrophytes*, and they live along the margin of ponds, lakes, rivers, canals, marshes, and bogs. The primary root is arrested, and numerous adventitious ones are developed, and the leaves are often smooth. This condition is well illustrated by some of the Forget-me-nots, for when growing on dry land they are hairy, but when living along the edge of a pond the hairs are lost. A true knowledge of the external structure of such plants can be obtained if the student will carefully examine such plants, and make notes of any modifications met with.

HYDROPHYTIC SOCIETIES.—When plants live in water, they are known as *hydrophytes*, and their structure differs widely from the other plants which we have studied. Their stems are slender, and the vascular bundles are not well developed, for the water supports the plants and thick strong stems are not required. Submerged leaves are generally much divided, and they contain no cuticle nor stomata. The floating leaves have the stomata arranged on the upper or exposed surface. Root-hairs are not developed, for all parts of the plant can take in water, etc. The structure of such plants should be carefully examined, and modifications looked for.

CHAPTER XXI

THE STUDY OF PLANTS IN THE FIELD

FIELD WORK.—There are few departments which deal with plant life that offer such a variety of topics for consideration as work in the field. The experience gained in the lecture-room and laboratory have laid the foundation upon which a sound knowledge of the identification of plants can be built. The subject can be pursued with a small outlay, for the necessary apparatus can be obtained for half-a-crown. These consist of hand lens, which will magnify four or five diameters, a knife, a pair of forceps, and a few pins. Thus equipped, the student should collect plants, and by means of a flora try to discover the names and characters of the common plants which grow in his district.

FLORA.—The word *flora* was introduced by the great Swedish naturalist Linnæus, for a catalogue of plants. To-day, we commonly speak of the British Flora, but this may mean (1) the whole of the plants living in the British Isles, or (2) a book in which they are described. The word can also be used in the following way. Each county possesses a collection of plants, and these differ somewhat from those found in other parts of the country. Thus the flora of Bedfordshire consists of the whole of the plants living in that county. What is true of each county is also true of each field, sand-dune, marsh, meadow, and lane. In this way it becomes possible to speak of the flora of the sea-shore, mountain, bog, or marsh, etc. The floras of to-day are the descendants of the floras of the past. For

each period in the history of the earth has possessed a flora which can be distinguished from all other periods.

NAMES OF PLANTS.—Most plants receive common names, but these differ in different localities, and much



FIG. 45.—Composite flowers. On the left is shown a head of ligulate flowers, and on the opposite side the ray and disc flowers on the same head. The smaller figures represent single flowers.

confusion arises in the mind of young botanists from their use. For instance, the Gorse is known as Whin or Furze, and, unless these names are known, one person may call it the latter name, and the person to whom he speaks

may not know the plant by this name. To overcome this difficulty, botanists give to each plant two names: the first name is known as the genus, and the second the species. Thus the Gorse is known as *Ulex*, and this represents the genus; but there are two plants which belong



FIG. 46.—Flower of Iris, showing the floral leaves. The floral leaves are arranged in two rows of three each.

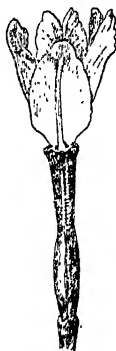


FIG. 47.—Flower of Iris. The outer leaves of the flower have been removed to show the leaf-like stigmas and a single stamen in front.

to the genus *Ulex*, and to distinguish them each one is given another name which is known as the species.

Thus *Ulex europæus* is the largest gorse.

„ *Ulex nanus* „ smallest gorse.

The student will see from this that a number of species are grouped to form a genus because they possess some

characters in common. This will be rendered clearer by the following table :—

Genus.	Species.	Common name.
Lamium	Purpureum	Purple Deadnettle.
„	Album	White „
„	Galeobdolon	Yellow Archangel.
Pyrus	Communis	Wild Pear.
„	Malus	Wild or Crab Apple.
„	Torminalis	Wild Service.
„	Aria	White Beam.
„	Aucuparia	Mountain Ash or Rowan Tree.

HOW TO IDENTIFY PLANTS.—The student should obtain a good British flora, and, when opportunities occur, plants should be collected and by means of the structure of the plants their position in the vegetable kingdom should be obtained.

CHAPTER XXII

A GENERAL REVIEW OF PLANT LIFE

DIVISION OF LABOUR.—In a busy workshop the labour is divided up among many men, each man performing a special kind of work, or *division of labour* is the rule. The work being divided up in this way enables a man to become a specialist in one department. There is a similar division of labour among the organs of one of the higher plants. Take the case of an oak tree, where—

(1) The roots fix the tree in the soil, and absorb from it water and minerals.

(2) The stem supports the leaves, and connects them with the root.

(3) The leaves represent a laboratory, where sugar is produced from carbon dioxide and water.

(4) The flowers are concerned with reproduction, and the formation of seeds.

Each special organ performs a different kind of work and the life of the plant depends upon each one being capable of carrying out its allotted work. Unicellular plants do not show as complete a division of labour as Multicellular ones, but it exists even in the case of *hæmatococcus*. (1) The red colour helps to absorb heat, so that the average life of the plant is maintained at a higher level. (2) The cell-wall protects the protoplasm from injury. (3) The chlorophyll helps in the formation of sugar. (4) The nucleus starts the division of the cell, by which means reproduction takes place.

WATER NECESSARY FOR PLANT LIFE.—The active life of plants can only be carried on where they are supplied

with water. In its absence, growth ceases, and the plant either dies or become dormant. The following is a summary, in the form of a table, of the work performed by water in the plant world:—

- (1) Water is the medium by which food enters the plant.
- (2) Water enters into the composition of the protoplasm, and all the organised structures found in plants.
- (3) Water is necessary for the growth of plants—without it the cells lose their turgidity, and they flag.
- (4) Water is the medium by which various substances are distributed throughout the plant.
- (5) Water forms a large portion of most plants—from 10 per cent. in seeds to 95 in very succulent plants.

AIR NECESSARY FOR PLANT LIFE.—In only a very few cases can plants live in the absence of atmospheric air. For green plants, it is an absolute necessity, for they obtain from it carbon dioxide and oxygen.

Carbon Dioxide.—The carbon dioxide in the external air does not exceed as a rule 0.04 per cent., but this is sufficient; for as fast as the green plant absorbs it, the movement of the air brings fresh supplies in contact with the leaves. It is necessary for the formation of sugar, and as it touches the surface of the leaf, it unites with water in the sap and forms carbonic acid. The only way in which organised carbon compounds can be made by green plants is from carbon dioxide in the air.

Oxygen.—Some of the oxygen in the air enters into plants, and it unites with some of the carbon compounds to form carbon dioxide. The respiration of plants produces energy and heat. Oxidation, as the union of oxygen with another element is called, is necessary for the active life of all plants.

Plants take in and give out Carbon Dioxide and Oxygen.—Green plants absorb carbon dioxide from the air, and split it up into carbon and oxygen, they keep the former element, but return the latter to the atmosphere. They also absorb free oxygen, this unites with carbon to form carbon dioxide, which is returned to the air. The taking in and splitting up of carbon dioxide depends upon the rays of the sun, and only goes on during the time the plant is exposed to light, but respiration is always going on.

CHLOROPHYLL NECESSARY FOR PLANT LIFE.—The importance of chlorophyll both to plants and animals cannot be overstated. In it commences those processes which lead to the formation of sugar and starch. Neither animals nor plants can live without the performance of the carbon assimilatory functions of chlorophyll. The starch, etc., in the bread we eat at breakfast comes through the chlorophyll, and without it, sooner or later, the whole of what we call life would cease to exist.

Sugar.—Of all the soluble substances which plants produce, none is of more importance than sugar. It is the starting-point of all the great processes in plants, and is probably the first substance that green plants form from water and carbon dioxide. In the germination of seeds, the starch, cellulose, or fats which they contain is changed into sugar, so that it can pass through the cell-walls to where growth is taking place.

Starch.—One of the common reserve materials which is stored up in seeds, stems, and roots is starch. Under the influence of light, green leaves form sugar, and this is removed to some other part of the plant where it is changed into starch. Whenever the growth of the plant, or the development of seeds require material, a ferment which exists in all plants converts it into sugar, and in this form it is removed to supply the demand (p. 82).

PLANTS BUILD UP COMPLEX SUBSTANCES FROM SIMPLE MATERIALS.—The food which green plants obtain consists of simple materials : such as water, carbon dioxide, carbonates, sulphates, phosphates, nitrates, etc. From these the living activity of plants form complex substances : such as sugar, cellulose, fat, proteins, and protoplasm. The energy used by the plants in producing the change from simple materials into complex substances can be obtained from the sun, and by oxidation.

ANIMALS REVERSE THE PROCESS.—Animals feed on proteins, starch, sugar, fats, water, and minerals. They obtain from these compounds energy and heat, and return so much carbon dioxide, water, and minerals to the air and soil. Thus animals use the compounds formed by plants, and convert them into materials fit for the food of plants.

PLANTS AID THE NUTRITION OF ANIMALS.—It is quite evident from the description given above, that plants aid the nutrition of animals, and that without them animals could not exist. Nearly all the food used (except water and a few minerals) by animals is prepared by plants, and from these the energy displayed by animals is obtained. The oxygen which plants give out can be used by animals for respiration.

ANIMALS AID THE NUTRITION OF PLANTS.—It is just as clear, that plants are deeply indebted to animals for their food. The food of plants, with very few exceptions, is prepared by animals. For they give out the very compounds which are necessary for the nutrition of plants.

THE FUNGI.—The plants which do not contain chlorophyll have some of their foods in the form of complex carbon compounds. They obtain much of the food they require from decomposing organic matters, or from host plants. Such plants are an exception to the general rule.

REPRODUCTION.—Of all the functions performed by plants, that of reproduction is one of the most interesting, and at the same time most difficult to understand. The table given below is a summary of the methods adopted by plants to reproduce their kind.

(1) Flowering plants reproduce by means of seeds, and vegetative organs. The seeds can be easily distributed (p. 26), and lessens the competition between plants belonging to the same species. Vegetative reproduction is a more direct method, for a portion of the body of the plant is separated from the parent, and this develops directly into a form like the parent.

(2) Non-flowering plants reproduce their kind by means of sexual and asexual spores, and they may also possess a vegetative method of reproduction. The sexual spore is formed by the union of two masses of protoplasm; but the asexual by the division of one mass of protoplasm.

(3) In both ferns and mosses, a well-defined alternation of generation can be distinguished (p. 146), but while flowering plants go through the same stages, they are not so easy to understand.

QUESTIONS

THE following questions are intended for revision, and to test the knowledge of the student. One of the best methods a student can adopt is to write the answers to several questions each week, and in this way to crystallise the knowledge gained.

CHAPTER I

1. What is "Nature Study," and what are its aims?
2. Of what value is "Nature Study," and what objects can be used for such study?
3. What methods would you suggest as likely to interest people in an out-door life, and to help them to understand nature?

CHAPTER II

4. Describe the structure of some common flower, and illustrate your answer by sketches.
5. All parts of flowers are said to be made up of modified leaves. Explain this.
6. How are the internal organs of a flower protected from rain and dew?
7. Of what parts is a pistil composed, and what does the ovary generally contain?
8. Make a sketch of the flower of the Sweet Pea, and describe how it differs in structure from the Buttercup.
9. What is a flower? Of what parts does it consist, and what are the structures and uses of the several parts?

CHAPTER III

10. What do you understand to be meant by *functions*? Illustrate your answer by examples.
11. What experiments would you perform to ascertain the functions of a stamen and a pistil?
12. Make a sketch of some common pistil, and enumerate the functions performed by the ovary, style, and stigma.
13. What is pollen, and how does it find its way on to the stigma?
14. Define pollination and fertilisation. How does pollination differ from fertilisation?

CHAPTER IV

15. Define the term *organ*, and give examples.
16. What is a fruit, and how do they liberate their seeds?
17. Shortly describe the fruit of the Orange. Is this a superior or an inferior fruit? How can you answer the question without having seen the flower?
18. Give a short account of how seeds are scattered.
19. Illustrate by sketches the structure of the seeds of the Pea and the Coffee Berry.
20. What functions are performed by fruits and seeds?

CHAPTER V

21. What conditions are necessary for the successful germination of seeds?
22. Explain how light, heat, and air act during the germination of seeds.
23. Why does the primary root of a Bean bend downwards when the seed germinates, and the stem grow upwards?
24. What is soil, and in what condition do plants obtain their food from it?
25. Give a sketch of one named seedling.
26. Draw young seedlings of Maize and Sycamore. How do the roots of the above seedlings differ from one another?

CHAPTER VI

27. Give a description of the structure of the terminal bud of the Horse Chestnut, and state how it differs from the bud of the Sycamore.
28. What is meant by a *growing-point*? Give examples.
29. What are dormant buds, and of what service are they to the plant?
30. How is the growing-point of the root protected from injury and how does it differ from that of the stem?
31. What differences are to be marked between the leaves of an expanding bud of Horse Chestnut, the same leaves when half-grown, and the fully formed leaves?

CHAPTER VII

32. State how you can distinguish a herbaceous stem from (1) a woody stem, and (2) a shrubby stem?
33. How does a corm differ from a bulb, and a rhizome from a tuber?
34. In a cross-section of a woody stem numerous rings can be seen. Explain as far as you can what they represent, and how they have been produced.
35. How do plants climb, and of what service is the climbing habit?
36. What is meant by *knots* in timber, and how have they been formed?

CHAPTER VIII

37. What are root-hairs, and what are their uses?
38. What is the structure of a root of a plant? How does a root differ from a stem? What goes on in a root when a plant is living and growing, and how is the structure of the root adapted for the purpose?
39. What important functions do roots perform?
40. How does a primary root differ from secondary and tertiary roots?

CHAPTER IX

41. Explain how foliage leaves grow on stems, and why the arrangements you describe are of advantage to the plant.
42. What parts are present in a typical foliage leaf?
43. How do compound leaves differ from simple ones? Illustrate your answer by sketches.
44. In a skeleton leaf the soft parts have disappeared, and only the veins remain. How can you prove that the veins of a leaf are connected with those of the stem?
45. What are stomata, and where are they found? How can you make a preparation to show their structure?

CHAPTER X

46. What is chlorophyll, and in what parts of plants can it be found? How would you prepare a solution of chlorophyll?
47. What important function does chlorophyll perform?
48. How would you proceed to prepare a starch print?
49. How does starch differ from grape sugar? What conditions are necessary for the formation of starch?
50. In what parts of plants would you look for starch, and how can you demonstrate its presence?

CHAPTER XI

51. Give a classification of plants based on the methods they adopt in obtaining food.
52. What is soil? Give a description of the formation of a soil?
53. Explain the work done by lime in a soil.
54. How would you proceed to ascertain the elements which a green plant must have for perfect growth?

CHAPTER XII

55. How do water plants differ from land plants in structure and mode of obtaining food?
56. What are parasites, and how do they differ from saprophytes?
57. What is a fungus? How does the nutrition of a fungus differ from that of a green plant?
58. Explain how the Dodder differs from the Mistletoe.
59. Write a description of the mode of life of the Sundew, Butterwort, and Bladderwort.
60. Do you know of any plants which live together to form a life-partnership? If so, describe them.

CHAPTER XIII

61. What do plants do with their food?
62. Give an account of the tests you would apply to distinguish starch, grape sugar, cellulose, and fats.
63. Classify the substances found in plants.
64. What is protoplasm? Where is it generally found, and what are its properties?
65. What are tissues, and what functions may they perform in plants?

CHAPTER XIV

66. Explain what you understand by respiration.
67. What changes do green plants produce in the composition of the atmosphere?
68. Heat is produced by respiration. Prove that external temperature has a marked influence on respiration.
69. How can you prove that plants give out carbon dioxide and take in oxygen?
70. Why do most plants need oxygen? From what source do they obtain it, and what important service does it perform in the plant?

CHAPTER XV

71. How can you prove that green plants give out aqueous vapour?
72. By what organs does the aqueous vapour leave the plant, and state how you can prove that your statement is correct?
73. How do plants prevent undue transpiration?
74. What is transpiration? Why do plants transpire?

CHAPTER XVI

75. Write a short essay on the colour of plants.
76. What functions do you suppose red, violet, or blue pigment may perform in leaves?
77. What influence has light on the growth of green plants?
78. How are autumn tints produced?

CHAPTER XVII

79. What is a flowering plant? How do flowering plants differ from non-flowering plants?
80. The Pea plant is said to be annual. Explain this.
81. What do you understand by the "life history" of a plant?
82. How is pollination produced in a Pea flower, and what changes do various parts of the flower undergo after fertilisation?

CHAPTER XVIII

83. Draw a section through the rhizome of a Fern. Describe the structure of the several parts shown in your drawing, and state their uses.

84. In what respects does a spore of a Fern resemble, and in what does it differ from a seed?
85. What do you understand by "alternation of generation"?
86. Where are the spores of a fern formed, and how are they dispersed? What do they produce on germination?
87. How would you procure a large number of healthy Fern prothalli?
88. Describe the structure of (1) a sorus; (2) a sporangium; (3) a spore.
89. How can Fern spores be obtained and germinated?
90. Explain how a Fern plant differs from and resembles the Pea plant.
91. Give drawings of antheridium, archegonium, and prothallus.
92. When a spore germinates, what does it produce?

CHAPTER XIX

93. How do cultivated plants generally differ from wild ones?
94. What is meant by the "struggle of existence" and "natural selection"?
95. Explain what is meant by *heredity* and *reversion*.

CHAPTER XX

96. Why do plants form "plant societies"? Describe one typical plant society.
97. Define what is meant by *xerophytes*, *mesophytes*, *hygrophytes*, and *hydrophytes*, and give examples.
98. What kinds of plants would you expect to find growing on (1) Sand-dunes, (2) Moors, (3) Marshes, (4) Ponds?

CHAPTER XXI

99. What do you understand by "The British Flora"?
100. Define *species*, *genus*, and *common name* as applied to a plant.

CHAPTER XXII

101. Explain what is meant by "division of labour."
102. What is the biological importance of water and starch?
103. Why is air necessary for plant life?
104. Chlorophyll is said to be of importance to both plants and animals. Explain this.
105. Plants are said to build up complex materials from simple food substances. Try and explain the processes by which a green plant can perform this important work.
106. How do plants aid the nutrition of animals, and animals the nutrition of plants?
107. Explain how fungi resemble animals in their mode of nutrition.
108. How do flowering plants reproduce their kind?

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